Journal of Agriculture and Rural Development in the Tropics and Subtropics

DITSL

Vol. 106 No. 1 2005

kassel university press

Journal of Agriculture
and Rural Development in
the Tropics and Subtropics

Volume 106, No. 1, 2005

Journal of Agriculture and Rural Development in the Tropics and Subtropics
formerly:
Der Tropenlandwirt. Beiträge zur tropischen Landwirtschaft und Veterinärmedizin,
Journal of Agriculture in the Tropics and Subtropics

ISSN 1612-9830

Publisher
German Institute f. Tropical and Subtropical Agriculture (DITSL GmbH), Witzenhausen
Association for Sustainable Development (GNE mbH), Witzenhausen
Institute for tropical Agriculture e.V., Leipzig
University of Kassel, Faculty of Organic Agricultural Sciences, Witzenhausen
Association of Agronomists in the Tropics and Subtropics Witzenhausen, e.V. (VTW)

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Orders may be placed at Kassel University Press, Diagonale 10, D-34127 Kassel (www.upress.uni-kassel.de), Fon ++49 (0)561 804 2159, Fax ++49 (0)561 804 3429 or at any bookstore.

Publishing House
kassel university press GmbH
www.upress.uni-kassel.de

Composition and Layout
Bierwirth & Gabele Softwaredesign GbR, Steinstr. 19, Postfach 1128,
D - 37201 Witzenhausen, http://www.bg-softwaredesign.de

Cover layout: Jochen Roth, Melchior v. Wallenberg, Kassel

Printed by: Uniprinter University of Kassel

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 106, No. 1, 2005, pages 1–14

Sawah First! The Cultural Ecology of Alang-Alang in a Rain Forest Margin Community

G. Burkard*

Abstract

Imperata cylindrica, or *alang-alang* as it is often referred to in writings on SE-Asia, is one of the most intensively studied weeds of the world. In investigating *alang-alang* related problems in a small holder community in the vicinity of the Lore Lindu National Park on the island of Sulawesi, Indonesia, this paper challenges some common claims about the origins, attached values and future perspectives of *alang-alang*. The sources of imperata infusion in the research area are neither linked to population pressure, nor to inadequate cropping techniques in dry land cultivation. Rather, *alang-alang* expanded as a reaction to the development of the wet rice sector which absorbs most of the time and labour of the farmers. Often being forced to abandon their dry land plots in order to manage their wet rice fields, farmers create ideal conditions for the grass to expand. However, whereas on the one hand *alang-alang* represents a major element of "criticality", the *alang-alang* plot as such offers important opportunities provided by other plants growing naturally in imperata sites. A culturally defined preference for rice subsistence as well as an orientation aimed at securing survival rather than enhancing profitability make an effective control of the weed difficult.

Keywords: Indonesia, rain forest margin, socio-economic security, weed control, wet rice, alang-alang, Imperata cylindrica

1 Introduction

This article discusses the socio-cultural and institutional implications of "*alang-alang*" (*Imperata cylindrica*) infestation in the vicinity of the Lore Lindu National Park (LLNP), Central Sulawesi, Indonesia. The research site is the village of *Rompo*, located in the Besoa valley, some 130 km to the south of the provincial capital Palu.[1] After the islands of Sulawesi experienced an unprecedented "cocoa boom" in the late 90ties, the fertile forest border zones of the Lore Lindu area became one of the major "cocoa

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[1] The survey was integrated into a number of research activities under sub-project A2: "Social Organization and Processes of Ecological Stabilization and Destabilization" of the STORMA Research Program, a collaborative research program of the German Universities of Göttingen and Kassel and the Indonesian Universities "Institute for Agriculture" (IPB) in Bogor and Tadulako University in Palu, Central Sulawesi. Fieldwork was conducted from March 2001 until April 2002 and from September 2003 until April 2004.

frontiers" in the region. Since then, competition for agricultural land among local and migrant smallholders has resulted in a large scale conversion of secondary forests, often involving encroachment into the protected zones of the National Park (BURKARD, 2002). However, the intensity of this far-reaching process is not at all uniform: while in the northern (Palolo), western (Kulawi) and eastern (Napu) valleys around LLNP perennial estates are taking over the formerly forested landscape, the Besoa valley in the South has been largely spared by this development. Its agricultural system is still dominated by a mix of wet rice (*sawah*) and dry land fallow cultivation in which perennial export crops play only a secondary role. Typical for the situation are "open gaps" in the forest canopy which offer suitable conditions for "light loving" weed-grasses of which *Imperata cylindrica* (called "*alang-alang*" in Indonesia) is the most dominant. Whereas *alang-alang* is not a major problem in the research villages located in other parts of LLNP, it represents the major element of "criticality" in Rompo [2].

In general, there are four inter-related characteristics of imperata which count for its high regenerative capacity and its potential to dominate the soil cover over wide areas: (1) its seeds can keep in the air for at least 16 months and are spread easily by natural processes, (2) it produces toxic (so-called "allelophatic") substances that may inhibit the growth of other species at the same time its dense web of underground rhizomes may crowd out competitors, (3) its capability to survive fire (it builds up new shoots even if the biomass above the ground is burned) contributes to the removal of shrub reserves and crop plants and (4) by producing only little organic litter it does effectively undermine the restoration of soil fertility. Equipped with such "infamous" qualities one should not wonder that until the end of the 70ties researchers showed little esteem for the "noxorious weed". Landscapes dominated by imperata were considered simply as "wasteland" or "green deserts" (i.e. GOUROU (1953); GEERTZ (1963); GEDDES (1970); SOERJANI (1980)). This however changed significantly in the 80ties which showed a remarked "re-evaluation" of the grass and its agricultural perspectives. Scientists from various disciplines emphasised its function as a custodian against soil erosion (SOERJATNA and MCINTOSH, 1980), its role in the local economy (EIJKMANS, 1995), its potential as fodder in animal husbandry (SOEWARDI and SASTRADIPRADJA, 1980), the qualities of its rhizomes as fertiliser (SHERMAN, 1980; PRANOWO, 1987) and its role in the local ecology in general (DOVE, 1987). In short: what once dominated the literature as a "problem", had now become if not a "solution", so at least an "opportunity" [3]. On the other hand, important presumptions persist in regard to the origins of *alang-alang* grasslands, at least as far as the role of human activity in the creation of this landscapes is concerned. Most studies on *alang-alang* perceive its appearance as a negative side effect of too intensive agricultural cultivation (i.e. EIJKMANS (1995)), or of too long cropping periods combined with too short fallow periods (FREEMAN, 1970; GEDDES, 1970; MISCHUNG, 1984). In other words: in one or the other way the phenomenon

[2] The research villages covered by sub-project A2 are Sintuwu and Berdikari in Palolo; Watumaeta and Wuasa in Napu, Bolapapu and Toro in Kulawi and Rompo in Besoa.

[3] *alang-alang* was even propagated as the preferred location for state sponsored transmigration sites (see BURBRIDGE *et al.* (1981); KUMOLO (1987)).

is linked to the *internal constraints* of tropical dry land systems themselves and their limited "carrying capacity" in sustaining larger populations. Factors *external* to the dry land sector are consequently overlooked by those studies. Little attention has been paid to the socio-cultural preferences in agriculture and the concomitant inter-relationships between different resource types (i.e. how *alang-alang* infestation in the dry land sector relate to intensification in the wet rice sector) as well as the role of the wider institutional environment (i.e. development programs or state policies) in areas where *alang-alang* infestation occurs. It is hoped that this article can contribute to widen our knowledge about the socio-cultural and institutional conditions of imperata expansion and point to some possible directions of its control.

This article is organised as follows: after an analysis of the inter-relationships of *alang-alang* with technological devices and modes of production in section 2, section 3 investigates the characteristics of *alang-alang* plots and analyses the imperata infestation in relation to clearing practices and peasant decision making. Further it highlights the indigenous perceptions (or the "local knowledge") on *alang-alang* held by the local population, before section 4 discusses the agricultural perspectives of imperata sites and points to the "*alang-alang* dilemma" as a part of a larger "development dilemma" in the research region.

2 Rice Subsistence First: Time Allocation and the Sawah-Alang-Alang-Complex

The village leaders of Rompo estimate that ca. 60% of the village territory is covered by *alang-alang* with most of the affected area being located on the numerous slopes surrounding the settlement. This figure relates to the whole *alang-alang* cover including plots abandoned since a long time and which are under the jurisdiction of the village administration. Imperata sites claimed as private property make up 31.3% of all plots *owned* by local families. *alang-alang* has not been created on purpose in Rompo, neither at present nor in the past. There are no hints for a consciously improvement of imperata plots for cattle crazing as has been reported from other parts in Indonesia (Seavoy, 1975; Brookfield *et al.*, 1995, p.183).

Shifting cultivation - practised at least until the mid 80ties - may be a causal factor for imperata emergence, but it was for sure not the decisive one for the present imperata expansion. The notion of improper shifting practices is too simplistic to explain the situation. Rompo farmers belonged to the *established* swidden farming type and practised a rather stable rotation system on secondary forest. Usually, one crop of local rice (*kamba*) preceded two seasons of secondary food crops (*palawija*), before the plot lay fallow (*bero*) for four years.[4] Following our informants, the creation of forest isles and intensive weeding effectively inhibited large scale imperata disturbance in the past. This opinion however is not shared by the Indonesian government whose negative attitudes towards shifting cultivation are well documented in the literature (see Dove (1987)). To government officials shifting cultivation is seen as the main cause for deforestation

[4] As Murray Li (2002, p.420) points out, relatively intensive swidden cycles are long established in Central Sulawesi and did not develop as a reaction against "degeneration" or "crisis".

and perceived as the one and only reason for *alang-alang* spread (EIJKMANS, 1995, p.21). The pressure to stop the "bad habits" of shifting cultivation became increasingly felt in the mid 80ties when local politics encouraged the villagers to expand wet rice (*sawah*) cultivation and when swidden agriculture was forbidden after the establishment of LLNP.[5]

The fact that subsistence (rice) and market production (*palawija*) which formerly were integrated into a single agricultural swidden system become now separated into an irrigated rice and a non-irrigated *palawija* sector under a system of sedentary agriculture had far-reaching consequences for the local ecology. Sawah cultivation in Rompo allows for two planting periods per year: from February until May and from August until December. Given the fact that the construction and maintenance of wet rice fields is extremely labour-intensive, farmers are often forced to abandon their annual dry land plots in order to take care for their *sawah*.[6] This tendency is intensified by the introduction of new rice hybrids that absorb significantly more working time than local varieties.[7] Harvest failures in rice cultivation are a serious problem in Rompo, due to birds, rats and pigs that have destroyed a considerable amount of rice harvests within the last years. The wet rice locations are often several km away from the village, which means that when the rice plants begin to ripen, farmers have to spend up to several weeks in temporary huts (*bambaru*) outside Rompo in order to safeguard their rice fields. Our survey revealed that spend 25 - 60 days a year in the *bambaru* close to their *sawah*. It is during the peak times in *sawah* cultivation that most farmers give up substantial parts of their dry fields.[8]

Usually, those dry fields are used for the cultivation of the cash crop maize. Thus, whenever a household has too much pressing work to do, rice subsistence is given priority. During the time dry fields are not cultivated, *alang-alang* recovers at a very fast rate converting abandoned dry fields into *alang-alang* plots within one season.[9] As table 1 shows, imperata infestation (or problems with other weeds) and declining soil fertility are only minor factors for the abandonment of land. In general annual dry fields are abandoned either because farmers lack capital and labor, or because they face a serious problem of time allocation (of course, both factors are empirically related).

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[5] Wet rice fields are known in Rompo at least since the 40ties; but occurred only rarely before the mid-eighties.

[6] Every season fields have to be ploughed and leveled, ditches have to be made anew, channels must be cleaned by digging before the work loaded transplanting of rice seedlings starts.

[7] Despite this disadvantage hybrids are preferred because of their shorter period of ripening. The most common varieties are the "cimandi" and "superwin" hybrids.

[8] Rompo villagers who experienced a significant rate of out-migration within the last years face now even more serious problems in the maintenance of their sawah fields due to a serious lack of man power.

[9] In average, *alang-alang* already appeared after the plot was abandoned by the farmers for two weeks. Thus, during our 2nd survey in Rompo during mid December 2002, four households that had no *alang-alang* plots during the 1st survey two months before, reported having *alang-alang* fields now due to the abandoning of their fields after they had to prepare their sawah after the last maize harvest.

Table 1: Reasons for abandonment of dry fields. Source: primary data. Farmers could mention several reasons.

Why plot abandoned?	*Wet Rice Farmer (n = 20)*	*Non-Wet Rice Farmer (n = 11)*	*Total*
Covered of weeds / alang	3	2	5
Declining fertility	2	4	6
Distance / steepness	6	4	10
Destroyed by wild pigs	5	5	10
Lack of capital/labour*	17	9	26
Lack of time to cultivate	14	5	19
Management sawah plots	18	0	18

*capital/labor as one factor because capital can substitute labor by mechanization and hired workers.

The number of farmers who had to abandoned at least one plot in 2003 is 45.4% among those who do not cultivate *sawah* and 83.9% among *sawah* cultivators. In statistical terms the relationship becomes even more obvious: the area of dry land covered by imperata rises in a systematic manner with the area of *sawah* under cultivation ($r = 0.48$; statistically significant with 0.01).[10]

Thus our findings challenge the common claims about the sources of *alang-alang*. In contrast to the general notion that imperata develops as a side-effect of "too intensive cultivation"[11] (Mischung, 1984; Dove, 1987; Eijkmans, 1995), the opposite seems to be the case in Rompo: When asked why there is so much *alang-alang*, 83.9% of the farmers stated that this is due to the fact that people often must abandon their land; only a minority of 16.1% believed that imperata-infestation in their village is linked to the fact that plots are used for too long cropping periods. This is not to say that all imperata-problems are caused by wet rice cultivation alone. Non-rice farmers experience problems of time allocation and imperata infestation as well, albeit on a smaller scale. What is to be stressed however is that this tendency became intensified with the introduction of new rice hybrids and the expansion of a cultivation system (*sawah*) that absorbed more working time than the "traditional" inter-cropping of dry rice and non-rice food crops and that segregated subsistence and market crops in two different types of resources: the *sawah* and the dry field.

[10] Consequently, 93.5% of our respondents affirmed a positive relationship between imperata infestation and wet rice cultivation.

[11] In most studies "too-intensive cultivation" is used synonymous with "too-short fallow periods".

As I have pointed out elsewhere, *sawah* cultivation can reduce the pressure on the forest cover. Given the fact that in comparison to dry land agriculture, wet rice production is characterized by a higher absorption of work force and lower returns to labor, it provides less time and surplus that could otherwise be invested in new land clearings (see BURKARD (2002, p.24ff)). Similarly, MARTENS *et al.* (2004, p.188) found that the "forest saving" effect of yield increasing technologies in the lowlands of the forest margin is stronger if new technologies are also labor intensive. However, one should remain careful with the long-term consequences of labor intensive agrarian systems. As PENDER (1999, p.4) points out, resource degradation and resource improvement are "multi-dimensional" (and therefore "relative") conceptions. Improvements in one type of resource or in one location (wet rice fields!) may well be associated with degradation of other resources or other locations (dry fields!). Further, our findings show not only that *alang-alang* can spread with the same intensity under the conditions of sedentary agriculture as it may spread under a shifting cultivation regime; on the contrary they point out that imperata expansion may even be *fueled* by tendencies towards more settled and technologically advanced agriculture.[12]

3 Coping with Alang-Alang: Indigenous Imperata Management and its Limitations

The common pattern of forest-grassland distribution in Rompo is for patches of imperata to be scattered throughout areas of secondary forest or cultivated area. Among half of all *alang-alang* sites are fallow plots covered by different species of which *alang-alang* has become the dominant vegetation (51.6%), the other half are locations characterised by light secondary forest where *alang-alang* entered open gaps via natural processes (48.4%). Such a fragmentation suggests that this landscape was only recently created. Although *alang-alang* is quite extensive, there is almost no mono-growth of imperata (so-called "sheet *alang-alang*") which is normally believed to be symptomatic for longer-lasting disturbances. Two factors may explain the absence of "sheet *alang-alang*" mono-growth in Rompo: (1) The absence of a pronounced and long-lasting dry season (rainfalls may occur during most months of the year) will forestall that *alang-alang* reaches a full fire climax, at the same time it will allow competing species to coexist with imperata.[13] (2) Until the present, only a part of the farmers prefers to clear grasslands exclusively by burning with the effect that shrub-reserves have only been partly removed by fire. Using a "cognitive anthropology" approach, thirty-three so-called "vernaculars" (plants distinguished by the indigenous people and their language) have been isolated as growing

[12] Thus farmers often argued that *alang-alang* has spread increasingly after the late-eighties, just at the time when sawah cultivation expanded and when shifting cultivation was replaced by permanent dry land agriculture!

[13] As SHIM (1993) has noted for Sarawak, under conditions of nearly year-round rains *alang-alang* "nearly always loses in competition with other weeds" (ibid, p.23). "Losing" would be an exaggeration in our case, as all respondents complain about the expansion of the weed. However, the limiting role of rains in the development of *alang-alang* mono-growth is obvious.

"naturally" in both site types.[14] As table 2. shows, the predominant tree species found in secondary forests could survive in a significant part of alang-sites.

Table 2: Occurrence of tree species in imperata sites (percentages in brackets). Source: Primary data.

Local name	*Scientific name*	*Alang-alang plots in open landscape (Type 1)*	*Natural "gaps" in secondary forest with imperata growth (Type 2)*
Bentunu	*Sterculia oblongata*	10 (66.7)	11 (68.8)
Palili	*Lithocarpus celebicus*	8 (53.3)	10 (62.5)
Lewunu	-	7 (46.7)	9 (56.3)
Belante	*Homalanthus populneus*	6 (40.0)	9 (56.3)

The "traditional" practice of clearing an imperata site is to cut the grass (*baparas*), dig the sods with hoes (*cangkulan*) and - seldom - to break the rhizomes by hand.[15] In difference to the clearing of secondary forest (which always requires the use of fire) in the case of *alang-alang* it is not first of all the *burnt*, but the *decayed* wastes of the bio-mass which functions as fertiliser. The improvement of soil fertility provided by the decay of rhizomes is not only recognised by most of our respondents; it is also the main reason given for the persistence of this method.[16] However, this system is extremely labour-intense. Thus the often cited finding of KUMOLO (1987, p.54) that imperata is more easy to clear than secondary forest is too simplistic: (1) The average number of total days our respondents needed to clear and prepare an *alang-alang* plot of 1 ha until the first seedlings could be planted was 22 as compared to 24 days in the case of clearing secondary forest; (2) the mean expenditures for plot conversion are Rp. 250.000 for 1 ha *alang-alang* and Rp. 300.000 for 1 ha of secondary forest. The savings of a modest two working days and Rp. 50.000 per ha however, do not compensate for the fact that plots "cleaned" (*dibersihkan*) from imperata are perceived as being less fertile than soils where secondary forest was removed.

Following our key-informants, *alang-alang* plots develop an acceptable fertility only after they have been planted with seasonal crops for at least three successive seasons without

[14] Besoa people divided them into 14 trees and shrubs, 16 grasses and three flowers. A presentation of all the species identified would be beyond the scope of this article which focuses on the socio-cultural and socio-economic aspects of *Imperata cylindrica*. A list of all vernaculars and their usage can be ordered from the author. Only 14 of them however, could be clearly identified and classified with their scientific names so far.

[15] Chemical clearing is only used by less than 10% of the farmers due to the lack of capital and access. More than 2/3 however believe that chemical clearing is the most effective means in rising the fertility of their imperata infested plots. The discrepancy between the preferred means of control and access to it is quite obvious.

[16] This may be the reason why more than 90% of the farmers interviewed approved the statement that soil fertility under *alang-alang* can still be improved.

interruption. Then the "light-loving" weed has been stopped by a natural process of "shading-out". On the other hand, if the plot is used for only one season and shading out is not maintained, imperata growth will recover even faster and stronger! The reality however is, that most often lack of time and capital do not allow for three consecutive cropping seasons (especially when households own wet rice fields). Some 65% of our respondents perceive the conversion of *alang-alang* as not worthwhile, compared to the investment of time and labour and the rather low harvest returns from the fields. Besides the fact that people do not use fertiliser in enhancing soil quality, the major "contextual" problem is that they do not use the converted plots for *periods long enough to make their investment worthwhile*! The most serious implication of the dilemma is that neither investments to rise plot productivity, nor to enhance the sustainability of the dry land sector in general are made.

Despite the problems *alang-alang* poses for the villagers, the fact that 93% of our respondents have at least once converted *alang-alang* into agricultural land shows that imperata sites are actually not land without agrarian perspective. An important question related to the willingness to convert imperata is therefore in how far *alang-alang* is perceived as a valuable resource by its users and on which basis people make decisions about plot conversion. Both questions are empirically related. For example, in deciding if a certain imperata plot should be converted or not *degree of slope* was much more often mentioned as a decisive factor among wet rice (*sawah*) owners than among pure dry land farmers. This is because *sawah*-cultivators valued the grass-cover on slopes close to their wet rice fields for the protective function it plays in safeguarding the wet rice fields against soil erosion.[17]

Besides "slope", there are another two major variables perceived as relevant in conversion: The first one, *reliability of ownership* is interesting, because one of the major findings of our broader research is that security of land tenure is quite strong in the whole LLNP area (Burkard, 2002, p.14). With grasslands however it is a different matter. In principle, ownership rights belonged to the first clearer of primary forest. The "contracting" waves of out-migration and in-migration which Rompo experienced within the last decades had a two-fold consequence: First, rights of a first clearer may "lapse" because the vegetation which defines such rights is lost by deforestation or because the original clearer already left the village. Second, in difference to secondary forests, most imperata plots are now under the jurisdiction of the village administration which claims

[17] Soerjatna and Mcintosh (1980, p.137) have pointed out that imperata plays an important role as a fast growing ground cover after deforestation not only in preventing soil erosion, but also in leaching. Similarly, Geddes (1970, p.11) has concluded that "land which is under grass is as effective at preventing erosion as it was under light forest" and Sherman (1980, p.129) believes that erosion under imperata is even less than under secondary forest. Given the fact that 61% of all plots in the sample are on slopes, the role of *alang-alang* as a custodian against soil erosion should indeed not be underestimated. Whereas most wet rice farmers acknowledged the protective function the grass fulfils on slopes; the idea that imperata should be more effective in preventing erosion than secondary forest however was rejected emphatically!

the solemn right of "grassland disposal" by virtue of the new village regulations drafted in 2001. Thus, overlapping claims may always impede the conversion of a plot.

The most decisive characteristic however, which make a plot "valued" as an agricultural resource is the presence of certain *indicator plants* which are mixed within *alang-alang*. To our own surprise, it is not (as one would expect) "intensity of imperata", "soil colour", the presence of certain tree species or the last harvest result, but the existence of four other competing weedy grasses which informs the farmer about the quality of an imperata infested plot. Following "local knowledge", as long as either "*vuvule*" (*Axonopus compresus* L), "*tonipo*" (*Crassocephalum crepidioides*), "*karokahi*" (*Bidens pilosa* L) or "*tile*" (*Themeda* sp) can be detected in the plot, *alang-alang* has not yet reached its climax and the plot is still fertile enough to be converted. Of these four weeds, *tonipo* (the "Japanese weed") is probably the most interesting. Local history tells that during the Japanese occupation the colonial power spread the seeds of the grass with aeroplanes in order to destroy the agricultural base of the Besoa people. The ultimate aim of the Japanese however was not achieved, because the weed turned out to be an excellent fodder for pigs.[18] Meanwhile *tonipo* has lost out significantly in competition with imperata.

The quality of *alang-alang* as fodder however is low. It is nutritious only for six weeks, after that its carrying capacity drops to 2.2 animal units per ha (SOEWARDI and SASTRADIPRADJA, 1980, p.168). The average number of livestock per household in Rompo is 0.8 for pigs and 0.3 for cattle. This figure points out that the carrying capacity of imperata sites as a fodder reservoir may in most cases be sufficient. Most owners of cattle and pigs however, use imperata only as a supplement. Besides its relative value as fodder, *alang-alang* is used by over 81% for construction, especially for the erection of houses and temporary huts (*bambaru*) close to their *sawah*. The well known use of imperata as a soil cover under perennial trees in order to control soil moisture under the crops is not widespread due to the fact that perennial cultivation is still at an early developmental stage in Rompo. In his study on land use among the Toba Batak in northern Sumatra, EIJKMANS (1995) notes that "peasants who cultivate a substantial part of their area with perennials show slightly more appreciation of *alang-alang* fields. The more annual crops are planted, especially wetland rice, the more this appreciation decreases"(ibid, p.142). Because the economic role of perennial trees is still minimal and because the usage of *alang-alang* is mainly confined to the construction and repair of the *bambaru*-sheds, the opposite is the case in Rompo where a higher percentage of wet rice cultivators could name useful advantages of imperata (83%) as compared to non-wet rice farmers (53%). All in all one must state that the degree of utilisation and economic value of *alang-alang* is far less than could be expected on the basis of the existing literature. However, what holds true for *alang-alang* as a "plant" does not necessarily hold true for the *alang-alang* plot as an "ecosystem". Whereas the value

[18] According to Dove (1984, cited in BROOKFIELD *et al.* (1995, p.193)) the "Japanese weed" is also known in Kalimantan where it is identified with *Chromolaena odorata* and surrounded by myths as well. BROOKFIELD *et al.* (1995) believe that the grass indeed expanded due to the fact that during the war the Dutch restrictions on burning were not applied.

attributed to imperata may be low, the value of the plot where imperata grows may be quite high. Of the 33 different vernaculars which grow in *alang-alang* plots, 27 are actively used by our respondents in their everyday life. The utilisation of these plants covers fertiliser, construction material, traditional medicine, fodder, firewood etc. Table 3 gives an impression of the diversified utilisation of these plants.

Table 3: Examples for utilisation of vernaculars occurring naturally in *alang-alang* plots. Source: primary data.

Local name	*Indonesian name*	*Scientific name*	*Utilisation*
Jambu Hutan	Jambu	Syzygium malaccensis	Medicine (stomach)
Vuvule	-	Axonopus compresus L.	Medicine (stomach)
Tile	-	Themeda sp.	Roof thatch
Rumput nipon	tonipo	Chromolaena odorata	Fodder
Enau / Aren	Aren	Arenga pinnata	Drink, Sugar
Danna	Alang-alang	Imperata cylindrica	House construction
Rengko rengko	Rumput kacang	Crotalaria anagyroides	Fertiliser, "alang-Killer"
Palili	-	Lithocarpus celebicus	Fire wood
Delupa	Bunga putih	Urena labota	Medicine (stomach)
Putisese	-	Ageratum conyzoides L	Medicine (desinfection)
Silaguri	-	Sida rumbifolia L	Medicine (stops bleeding)
Bure bure	-	Glochidion sp.	Rope

Therefore it is misleading to conclude that a low level of *alang-alang* utilisation automatically implies that imperata *sites* are perceived as land without economic value which everyone is willing to convert. For instance, the reason given by some of our respondents for the non-use of fire in clearing imperata was that only if plots are kept safe from fire will the replenishment of valuable plants in their *alang-alang* plots be sustained! The situation in Rompo does neither fit the image of imperata as an opportunity as it is portrayed by some "*alang-alang* enthusiasts", nor does it fit the stereotype of the "infamous weed". Rather, *alang-alang* plots should be understood contextually, as an ecosystem which may pose a problem in same arenas / locations (*palawija* cultivation) at the same time it may offer opportunities in other arenas (i. e. traditional medicine provided by "collateral" plants which grow within imperata sites). The related population views *alang-alang* as a "problem" in the sense that too much plots are infested which makes dry land agriculture increasingly difficult; but this does not mean that they want to relinquish the *alang-alang*-plot as an ecosystem in general. In regard to the first aspect, the role of perennials in eradicating *alang-alang* becomes increasingly important. As will be seen in the last section, from a "biological" point of view, perennials can be a way of overcoming the dilemma; the abandoning of land and the spread of *alang-alang*

in agricultural plots. In socio-cultural terms however, they are not a "cure-all-remedy" for all the problems involved.

4 Perennial Expansion and the Agricultural Perspectives of Alang-Alang

For the Indonesian government, *alang-alang* plots are land lying idle, land which is not used effectively and land which impedes the nations development (DOVE, 1987; EIJKMANS, 1995). Driven by the fear that non-compliance with state policies could lead to a withdrawal of government subsidies[19], in April 2001 the village administration issued several regulations in regard to natural resource use. The most important rules are that (1) all plots must be cultivated permanently, (2) land not used effectively (= *alang-alang*!) can be withdrawn by the village authorities and (3) allowances to open forest are only issued when the applicant has converted all his imperata plots before. Given the socio-economic circumstances and constraints outlined above, it is clear that these "rules" are rather meant to please higher authorities than they represent institutional devices which are really monitored and enforced. However, they point to the future direction, the dry land sector is expected to develop. As the foregoing sections showed, local people perceive *alang-alang*-plots neither exclusively in terms of a "problem", nor exclusively in terms of an "opportunity"; but they would appreciate if the number of imperata infested plots would be reduced. Although imperata is intolerable to shade and active cultivation my suppress its growth, the major problem Rompo villagers face is that this effort must be constantly maintained. In the recent past however, a growing number of farmers have started to plant perennials in part of their *alang-alang* fields. For instance, within the last three years 22.5% of our respondents planted "*kemiri*" (*Aleurites moluccana*) and 35.4% planted cocoa inside of *alang-alang* plots. Considering the high vulnerability of *alang-alang* to shade, at first glance the trend of planting perennials seems to be promising. The general opinion is that more than cocoa itself, it is the cocoa-bound shadow tree "*gamal*"[20] (*Gliricidia sepium*) which contributes most to the shading out of *alang-alang*. Once established, by absorbing less labour than annual plots, perennial stands may reduce the time pressure for the farmers and may suffer less degradation in case they are temporarily abandoned. It is these characteristics which make cocoa the ideal remedy against land degradation in the eyes of regional policy makers and local NGO´s.[21]

In general, perennial expansion in the research area occurs within an evolutionary process, in which the area for perennial crops is first extended with annual crops being inter-planted. With the course of time perennials dominate more and more the mixed cropping stands and inter-cropping decreases. In the LLNP area, cover crops within the mixed system consist mainly of maize, peanuts and red beans. After the village head

[19] This was the painful experience of the neighbouring village of Katu which still practices traditional shifting cultivation inside LLNP and which was punished with a stop of all government programs and subsidies.

[20] "Gamal" is actually an abbreviation for "ganyang mati *alang-alang*"; literally the "*alang-alang*-ko-killer".

[21] 40% of the villagers received either government or non-government subsidies in form of cocoa seedlings.

conducted a successful trial series in his private "experimental plot", sweet potatoes (*Convolvulaceae*+) have become the most popular cover crops in Rompo. The fact that over 80% of our informants have plans to plant perennial crops in imperata sites should not lead us to the fallacy that in the foreseeable future Rompo will become an export village, dominated by cocoa estates and free of *alang-alang* infestation. One aspect of the local imperata dilemma is for sure that under the given circumstances (low capitalisation, missing access to credits, frequent harvest failures) household decision making will always be governed by the "security first" principle. Thus it will always prioritise subsistence concerns over market production ("*sawah* first!"). In case a farmer has money to afford fertiliser, the general pattern is to use it up for the fertilisation of wet rice first. Only when a "rest" is left, will it be used for market crops. Cocoa has only recently entered the Besoa area and is planted in Rompo since less than four years. Given limited knowledge and limited resources among the farmers, starting cocoa cultivation for the first time may be a very risk-loaded exercise (see EIJKMANS (1995, p.164). The life cycle of perennial crops involves that during the first three years (as long as trees do not bear fruits) investment costs may exceed the benefits of the first harvests. Therefore, in terms of security fast yielding annuals are vital to overcome the first unproductive years of perennials. It is indicative for the situation, that the introduction of the export crop cocoa was supplemented by the introduction of a typical subsistence cover crop of almost no local market value: sweet potato!

In the Lore Lindu region, the arrival of cocoa is intrinsically linked to the Buginese migrants from South Sulawesi. Transferring a plant from one location to another (i.e. from South to Central Sulawesi) however is more than a matter of locality, but involves the transfer of a certain security conception which surrounds this specific plant. In the research region, security is obtained by a strategy of mixed cropping which is aimed at providing a high variety of cultivated plants in order to secure at least one crop in case of harvest failures. The predominant characteristic of this strategy is "diversification". Among the Buginese on the other hand, security is derived from the "intensification" of one product of high economic value which is usually cocoa (BURKARD, 2002, p.18ff). Whereas the local security system aims at "survival in bad years", the perennial system aims at "maximum production in average years" (EIJKMANS, 1995). One cannot expect that local communities adapt to such a fundamental change of their security conception within a short period of time. Consequently, the average area farmers are willing to plant with cocoa is 0.4 ha; which make up 1/3 of the average imperata area controlled by the same individuals. In the neighbouring Napu valley we found that after cocoa trees in mixed stands reached the point where their increasing shade did not anymore allow for annual cover crops, people encroached into the National Park in order to plant diverse annual (*palawija*) food crops because they perceived the reliance on a single export product (cocoa) as a threat for their existence (ibid, p.21). If one is allowed to speculate about a similar development in the Besoa valley, the opening of new plots for annuals would then again provide new "gaps" for imperata to invade. Thus perennials could set in motion a process they once were introduced to combat. Therefore, the need to intensify *alang-alang* fields cannot be solved in a sustainable manner by the

spread of perennials and their biological advantages alone without taking deep rooted convictions and mechanisms of risk control into account.[22] Neither in developing the wet rice sector (the source of *alang-alang* infestation), nor in expanding perennial cultivation (the proposed remedy for *alang-alang* infestation) did the state take notice of the local conception of socio-economic security and of the role imperata plays in the wider cultural ecology of the Besoa people.

References

Brookfield, H., Potter, L. and Byron, Y.; *In Place of the Forest: Environmental and Socio-economic Transformation in Borneo and the Malay Peninsula*; United Nations University Press, New York; 1995.

Burbridge, P., Dixon, J. and Soewardi, B.; Forestry and Agriculture: Options for Ressource Allocation in Choosing Lands for Transmigration; *Applied Geography*; 1:237–258; 1981.

Burkard, G.; Stability or Sustainability? Dimensions of socio-economic Security in a Rain Forest Margin; Storma Discussion Paper Series No. 7, Bogor; 2002.

Dove, M.; *Manusia dan Alang-Alang di Indonesia*; Gadjah Mada Press, Yogyakarta; 1987.

Eijkmans, H. J.; Profitability or Security. Decision Making on Land Use among Toba Batak Peasants in North Sumatra, Indonesia; Nijmegen Studies in Development and Cultural Change; 1995.

Freeman, J. D.; Report on the Iban; Monographs on Social Anthropology No. 41, New York; 1970.

Geddes, W. R.; Opium and the Miao: A Study in Ecological Adjustment; *Oceania*; 41(1):1–11; 1970.

Geertz, C.; *Agricultural Involution. Processes of Ecological Change in Indonesia*; Berkeley; 1963.

Gourou, P.; *The Tropical World. Its Social and Economic Conditions*; Longmans, London; 1953.

Kumolo, I.; Peranan Alang-Alang di Proyek Transmigrasi Baturaja; in: *Manusia dan Alang-Alang di Indonesia*, edited by Dove, M.; 43–66; Gadja Mada Press, Yogyakarta; 1987.

Martens, M., Zeller, M. and Birner, R.; Does Technical Progress in Agriculture have a Forest Saving Effect? Evidence from Central Sulawesi; in: *Land Use, Nature Conservation and the Stability of Rain Forest Margins in Southeast Asia*, edited by Gerold, G., Fremerey, M. and Guhardja, E.; vol. 32 of *Environmental Science*; Springer, Berlin; 2004.

Mischung, R.; Seßhaftigkeit und Intensivierung beim Brandrodungsfeldbau. Eine Fallstudie aus Nordwest-Thailand; *Paideuma*; 30:241–255; 1984.

Murray Li, T.; Local Histories and Global Markets: Cocoa and Class in Upland Sulawesi; *Development and Change*; 33:415–437; 2002.

[22] To put it more concretely: as long as national health services are not improved and *alang-alang* fields produce the bulk of the locally used medicines, high cocoa prices will not be able to close the gap between potential and actual use of imperata plots.

PENDER, J.; Rural Population Growth, Agricultural Change and Natural Resource Management in Developing Countries: A Review of Hypotheses and some Evidence from Honduras; TPTD Discussion Paper Series 48, Washington; 1999.

PRANOWO, H. A.; Eksploitasi Alang-Alang di Hutan Lindung di Lereng Gunung Merapi; in: *Manusia dan Alang-Alang di Indonesia*, edited by DOVE, M.; 133–166; Gadja Mada Press, Yogyakarta; 1987.

SEAVOY, R. E.; The Origin of Tropical Grasslands in Kalimantan, Indonesia; *Journal of Tropical Geography*; 40:48–52; 1975; p. 49.

SHERMAN, G.; What Green Desert? The Ecology of Batak Grassland Farming; *Indonesia*; 29:113–149; 1980.

SHIM, P. S.; Imperata Cylindrica Grasslands in Malaysia; in: *Imperata Grasslands in SE-Asia: Summary Report from Indonesia, Malaysia and the Philippines*, edited by VANDENBELDT, R. J.; The Forestry/Fuelwood Research and Development Project, Report #18; Winrock International, Washington, D.C, Bangkok; 1993.

SOERJANI, M.; Symposium on the Prevention and Rehabilitation of Critical Land in an Area Development; Proceedings of Biotrop Workshop on Alang-Alang No. 5, Bogor; 1980.

SOERJATNA, E. S. and MCINTOSH, J. L.; Food Crops Production and Control of Imperata Cyclindrica on Small Farms; Proceedings of Biotrop Workshop on Alang-Alang No. 5, Bogor; 1980.

SOEWARDI, B. and SASTRADIPRADJA, D.; Alang-Alang an Animal Husbandry; Proceedings of Biotrop Workshop on Alang-Alang No. 5, Bogor; 1980.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 106, No. 1, 2005, pages 15–27

Variety and Cultivation-practice Influences on the Growth Characteristics and Yield of Maize (*Zea mays* L.) under Drought Stress at Flowering

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Abstract

In northeast Thailand, maize (*Zea mays* L.) is mainly grown under rainfed conditions. In this region, frequent dry spells are often the cause of periodic drought-stress that leads to decreased yields, especially during the critical growth stages. The objective of the study was to identify and assess variety and cultivation-practice effects on the growth and yield of maize under temporary drought stress induced during the flowering stage. Under controlled soil-moisture conditions, three varieties (*Suwan5* - open-pollinating; *Big717* and *Big949* - single-cross hybrids) and five cultivation practices (conventional (CT); mungbean (*Vigna radiata* (L.) Wilzek) residue (Mn); spineless mimosa (*Mimosa invisa*) live mulch (Mi); manure (Ma); and plastic mulch (Pl) were studied for two cropping seasons.

There were significant variety differences, apparently independent of the cultivation practices. The two hybrid varieties produced significantly higher grain yields than the open-pollinating variety, i.e., *Big717* > *Big949* > *Suwan5*. The effects of cultivation practices were less prominent, with the exception of *Suwan5*, for which Mn, Mi, and Ma significantly reduced grain yields compared to CT and Pl. *Big717* showed no significant differences between the treatments; *Big949* showed significant treatment response only for the second crop, particularly for the Ma treatment. Overall, the highest average yields were produced by Pl; the lowest by Ma. However, there were no significant differences for the total aboveground biomass between cultivation practices, but between varieties -i.e., *Suwan5* and the two hybrids. The two hybrids had clearly higher harvest indexes (HI) than the open pollinating variety. For *Suwan5* and *Big949* HI was consistently lowest with the Ma treatment. The general trend of the tasseling-silking interval (TSI) was *Big949* > *Suwan5* > *Big717*. For *Big717*, TSI was not affected by any cultivation practices. For the other two varieties, Ma showed longest TSI. *Suwan5* grew more vigorously than the other varieties at the early vegetative stage. Within the varieties, the tallest plants were observed with Ma.

The effects of cultivation practices on the grain yield were less prominent than the variety effects; in some cases the practices, particularly Ma, even had a negative effect on the yield. Therefore, variety selection is still a potential management tool that can effectively control the effects of drought stress on the plants. It is however highly recommended

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that further studies should investigate plant responses for drought-stress periods during other growth stages and with different degrees of drought stress. On-farm trials under uncontrolled drought-stress conditions should be also carried out.

Keywords: cultivation practice, drought stress, maize, Thailand, Zea mays L.

1 Introduction

In the rainfed areas of northeast Thailand, maize is an important -often dominating- crop (Manupeerapan and Grudloyma, 2001). Erratic rainfall is common in this part of the country and dry spells often lead to periodic drought stress. These drought-stress periods frequently cause a significant decrease in the yields, particularly if they occur during the critical flowering stage (Doorenbos and Kassam, 1979; Musick and Dusek, 1980; NeSmith and Ritchie, 1992; Çakir, 2004). In the region, maize is usually grown continuously -sometimes twice a year-, but often also in rotation with mungbean (*Vigna radiata* (L.) Wilzek). Most of the varieties grown are commercial hybrids; few farmers use open-pollinating varieties. The dominating cultivation and crop-husbandry practices are conventional, with disk-ploughing, the application of pre-emergence herbicides, two mineral fertilizer applications and harvesting by hand (Cho, 2003). Crop residue is commonly burnt before the following cultivation cycle, particularly before the second growing season. Recently, some farmers began to apply cattle manure. Spineless mimosa (*Mimosa invisa*) has been introduced as live mulch for nitrogen fixation (Chotechaungmanirat, 1997). Generally, the maize-production system is well established and accepted by the farmers. However, yield losses due to unpredictable dry spells during the growing period remain a crucial problem that has not been addressed successfully in the area. As there are no significant irrigation resources in the region, solutions need to be based on variety selection, and soil and crop-management practices. The objective of the study was to identify and assess variety and cultivation-practice effects on the growth and yield of maize under temporary drought stress induced during the flowering stage.

2 Materials and Methods

The study was conducted in 2003 (first crop) and 2004 (second crop) at the Agricultural Systems Experimental Farm of the Asian Institute of Technology (AIT), about 30 km north of Bangkok.

The maize plants were grown in cylindrical plastic containers (55 cm diameter; 85 cm high) filled with soil to a depth of 75 cm (about 178 liters). The soil used for the experiment was a clay loam (27% sand, 29% silt, 44% clay) with pH 6.6 and with 2.03% organic matter. In each container, 2 plants were grown. For the monitoring of soil moisture, gypsum resistance blocks were buried at depths of 15, 30 and 60 cm. Since the soil moisture was controlled in this experiment, the containers were housed in a translucent rain shelter to prevent the plants from receiving natural rainfall. The initial soil-water holding capacity was 40% at field capacity and 10% at wilting point. Initially, all treatments were watered regularly and kept at soil-moisture contents between field capacity and 60% of the available soil moisture. Drought stress was introduced at the

flowering stage. For this, water supply was suspended for 15 days until the soil moisture content reached very closely to the wilting point. After that, the plants were watered as usual.

The varieties tested were *Suwan5*, an open-pollinating variety, and two single-cross hybrids, *Big717* and *Big949*. Fertilizer was applied at super-optimum rates to eliminate the influence of nutrient limitation to crop development. Five cultivation practices were evaluated, i.e., (i) conventional practices - no residues incorporated (CT); (ii) mungbean (*Vigna radiata* (L.) Wilzek) residue incorporated as practiced in a mungbean - maize rotation at the rate of 4.50 t ha^{-1} (Mn); (iii) spineless mimosa (*Mimosa invisa*) live mulch intercropped and incorporated at the rate of 6.25 t ha^{-1} (Mi); (iv) cattle manure incorporated at a rate of 20 t ha^{-1} (Ma); and (v) mulching with commercial plastic sheeting as a control treatment for the best soil-moisture conservation (Pl).

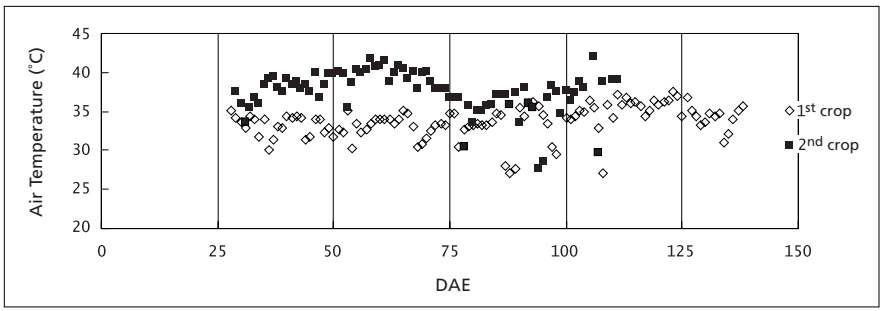
Soil moisture was monitored daily at three depths (15, 30 and 60 cm). Plant growth and development stages of each plant were recorded. At harvest, aboveground biomass of all plant components was measured. Basic climatic data i.e. air temperature and relative humidity was recorded daily. Plant height was measured at 30, 45 and 70 days after emergence (DAE).

The experiments were arranged as a randomized complete block design (RCBD), with five replications. One-way statistical analysis of variance was performed to identify the effects of treatments on biomass, grain yield, plant height and tasseling-silking interval (TSI). The least significant difference test (LSD) at $P < 0.05$ was used to indicate the differences between the treatments.

3 Results and Discussion

Overall, grain and biomass yields of the second crop were significantly lower than the fist crop, most likely due to the high air temperatures during the second growing season (Figure 1). During the second growing season, the maximum air temperatures under the rain shelter were over 40 °C – which is the general high threshold temperature for plants – for a period of 15 days.

Figure 1: Maximum air temperatures under the rain shelter for both crops.



WICKENS (1998) depicted that above 40 °C many of the molecules involved in the intermediary pathways (e.g. adenosine triphosphate, ATP), are unstable. This has negative effect on plant development and grain formation. However, the general observed trends and differences between varieties and treatments are similar for both cropping periods.

3.1 Plant Growth and Development

Suwan5 grew more vigorously at the early vegetative stage (measured 30 DAE) than the other varieties (Tables 1 and 2). There were no significant differences between the treatments at the fully-grown stage (measured 70 DAE). Within the varieties, the tallest plants were observed with the Ma treatment.
This could be due to the high mobility of organic phosphorous in the manure which may have led to better phosphorus availability to the plants at the early growth stages. Based on results reported in the literatures and their own studies, PARHAM *et al.* (2002) hypothesized that the high mobility of manure-P can be attributed to increased microbiological activities induced by manure.

3.1.1 Tasseling and Silking

Tasseling of *Suwan5* (47 DAE) was significantly later than *Big717* and *Big949* (45 DAE). For *Suwan5*, the treatments had no effects on the tasseling date. For both hybrid varieties, early tasseling was only found in the Ma treatment in the first crop.
Due to the high temperatures during the second cropping season -compared to the first crop-, silking was delayed by 3 days for *Suwan5*, 2 days for *Big949*, and 1 day for *Big717*.

3.1.2 Tasseling - Silking Interval (TSI)

Under normal environmental conditions, pollen shedding begins about 2 to 3 days before silking. Drought stress just before or during the flowering period causes a delay in silking that can be measured as an increase in the length of the tasseling silking interval (TSI) (RIBAUT *et al.*, 1995). In this study, with water stress introduced at the flowering stage, tassels were produced about 3 to 11 days before silking, depending on the treatments. The general trend of the resulting TSI for both crops was *Big949* $>$ *Suwan5* $>$ *Big717* (Table 3). *Big717* was not affected by any treatment. For the other two varieties and both crops, the Ma treatment had the longest TSI.

3.2 Grain Yield

3.2.1 Variety Response

There were marked variety differences, apparently independent of the cultivation practices (Table 4). For all treatments and both cropping seasons, the two hybrid varieties produced significantly higher yields than the open-pollinating variety, i.e., *Big717* $>$ *Big949* $>$ *Suwan5*. The differences between *Big717* and *Suwan5* were 76% for the first crop and 47% for the second crop.

3.2.2 Cultivation-practice Response

The effects of cultivation practices were less prominent, with the exception of *Suwan5* (Table 4). For *Suwan5*, the Mn, Mi, and Ma treatments significantly reduced grain yields compared to the CT and PI treatments for both crops, with differences of up to 90% (second crop). *Big717* showed no significant differences between the treatments;

Table 1: Plant-height development measured on 30, 45, and 70 DAE for the first crop.

Cultivation practice *	*Height (cm)*									*Practice mean* ‡		
	30 DAE †			*45 DAE* †			*70 DAE* †			*30 DAE*	*45 DAE*	*70 DAE*
	Suwan5	*Big717*	*Big949*	*Suwan5*	*Big717*	*Big949*	*Suwan5*	*Big717*	*Big949*			
CT	125.3 ^{b}	115.4	119.7	187.3	193.5	188.3	222.2	200.7	230.5	120.1 ^{bc}	189.7	217.8
Mn	122.7 ^{b}	110.0	116.4	178.2	183.8	195.0	204.8	203.5	230.0	116.4 ^{bc}	185.7	212.8
Mi	133.1 ^{ab}	124.7	121.5	190.7	197.0	199.3	238.8	211.5	232.0	126.4 ^{ab}	195.7	226.3
Ma	152.5 ^{a}	122.8	139.1	207.2	191.6	202.6	239.0	203.0	240.5	138.1 ^{a}	200.5	227.5
PI	113.8 ^{b}	112.6	116.8	178.6	184.2	193.8	220.5	197.1	227.5	114.4 ^{c}	185.5	215.0
Variety mean §	129.5 ^{A}	117.1 ^{B}	122.7 ^{AB}	188.4	190.02	195.8	224.4 ^{A}	203.2 ^{B}	232.1 ^{A}			
Statistical analysis ¶												
Practice	0.030	NS	NS	NS	NS	NS	NS	NS	NS	0.001	NS	NS
Variety	-	-	-	-	-	-	-	-	-	0.030	NS	0.000
Block	NS	NS	NS	NS	NS	NS	0.012	NS	NS	NS	NS	0.028
Pract. × Variety	-	-	-	-	-	-	-	-	-	NS	NS	NS

* CT: conventional cultivation practice (removed residues); Mn: mungbean residue incorporated; Mi: spineless mimosa (*Mimosa invisa*) live mulch, intercropped; Ma: cattle manure incorporated; PI: mulching with commercial plastic sheeting.
Values in †,‡,§ followed by the same letters or with no letters are not significantly different according to LSD test at $P \leq 0.05$; † Mean comparison within varieties in each column, ‡ Mean comparison between practices; § Mean comparison between varieties; ¶ Values show significant levels. NS: non-significant at $P > 0.05$

Table 2: Plant-height development measured on 30, 45, and 70 DAE for the second crop.

Cultivation practice *	*Height (cm)*									*Practice mean* ‡		
	30 DAE †			*45 DAE* †			*70 DAE* †			*30 DAE*	*45 DAE*	*70 DAE*
	Suwan5	*Big717*	*Big949*	*Suwan5*	*Big717*	*Big949*	*Suwan5*	*Big717*	*Big949*			
CT	103.4	94.6	89.7 ^{b}	162.8	161.1	161.5	177.3	157.4	177.9	95.9 ^{ab}	161.8	169.7
Mn	104.5	93.8	88.8 ^{b}	161.4	160.6	163.6	173.6	162.5	183.8	95.7 ^{b}	161.9	173.3
Mi	103.9	101.2	97.5 ^{a}	166.3	165.4	163.5	166.1	167.7	182.4	100.9 ^{a}	165.1	172.1
Ma	107.2	99.7	95.8 ^{ab}	171.3	165.4	163.1	170.4	164.8	173.4	100.9 ^{a}	166.6	169.5
Pl	96.3	90.1	83.4 ^{c}	158.8	155.2	155.0	173.1	152.6	175.4	89.9 ^{c}	156.3	167.0
Variety mean §	103.1 ^{A}	95.9 ^{B}	91.0 ^{C}	164.1	161.5	161.3	171.4 ^{A}	161.0 ^{B}	178.6 ^{A}			
Statistical analysis ¶												
Practice	NS	NS	0.008	NS	NS	NS	NS	NS	NS	0.000	NS	NS
Variety	-	-	-	-	-	-	-	-	-	0.000	NS	0.002
Block	NS	NS	NS	NS	NS	NS	NS	0.035	NS	NS	NS	0.010
Practice × Variety	-	-	-	-	-	-	-	-	-	NS	NS	NS

* CT: conventional cultivation practice (removed residues); Mn: mungbean residue incorporated; Mi: spineless mimosa (*Mimosa invisa*) live mulch, intercropped; Ma: cattle manure incorporated; Pl: mulching with commercial plastic sheeting.
Values in †,‡,§ followed by the same letters or with no letters are not significantly different according to LSD test at $P \leq 0.05$; † Mean comparison within varieties in each column, ‡ Mean comparison between practices; § Mean comparison between varieties; ¶ Values show significant levels. NS: non-significant at $P > 0.05$

Table 3: Tasseling - silking intervals (TSI) of the tested varieties in relation to cultivation practices.

Cultivation practice *	*First crop*				*Second crop* ‡			
	TSI (days) †			*Practice mean* ‡	*TSI (days)* †			*Practice mean* ‡
	Suwan5	*Big717*	*Big949*		*Suwan5*	*Big717*	*Big949*	
CT	4.1 ^{b}	3.8 ^{b}	6.3 ^{bc}	4.7 ^{c}	5.5	5.1	9.8 ^{ab}	6.8 ^{ab}
Mn	5.7 ^{b}	4.7 ^{ab}	6.1 ^{c}	5.5 ^{bc}	8.9	5.1	7.3 ^{bc}	7.1 ^{ab}
Mi	4.3 ^{b}	5.3 ^{a}	7.7 ^{ab}	5.8 ^{b}	9.6	6.4	8.5 ^{abc}	8.2 ^{ab}
Ma	9.7 ^{a}	4.5 ^{ab}	8.8 ^{a}	7.7 ^{a}	9.2	6.1	11.4 ^{a}	8.9 ^{a}
PI	5.4 ^{b}	3.3 ^{b}	6.3 ^{bc}	5.0 ^{bc}	7.4	6.0	6.5 ^{c}	6.7 ^{b}
Variety mean §	5.8 ^{B}	4.3 ^{C}	7.0 ^{A}		8.1 ^{A}	5.8 ^{B}	8.8 ^{A}	
Statistical analysis ¶								
Practice	0.001	NS	0.004	0.000	NS	NS	0.037	NS
Variety	-	-	-	0.000	-	-	-	0.000
Block	0.033	NS	0.027	NS	NS	NS	NS	NS
Practice × Variety	-	-	-	0.001	-	-	-	NS

* CT: conventional cultivation practice (removed residues); Mn: mungbean residue incorporated; Mi: spineless mimosa (*Mimosa invisa*) live mulch, intercropped; Ma: cattle manure incorporated; PI: mulching with commercial plastic sheeting.
Values in †,‡,§ followed by the same letters or with no letters are not significantly different according to LSD test at $P \leq 0.05$; † Mean comparison within varieties in each column, ‡ Mean comparison between practices; § Mean comparison between varieties; ¶ Values show significant levels. NS: non-significant at $P > 0.05$

Big949 showed significant treatment response only in the second crop, particularly for the Ma treatment which produced only 10% of PI and 20% of CT. Overall, the highest average yields were produced by PI; the lowest by Ma.

Manure application (i.e., the Ma treatment) is a soil-quality improvement practice recommended by the extension service. Manure has been reported to improve soil properties (Sommerfeldt and Chang, 1985) and crop yield (Ginting *et al.*, 1998; Parham *et al.*, 2002; Sutton *et al.*, 1986) especially when combined with fertilizer applications (Chivenge *et al.*, 2004). However, Ma showed the overall lowest grain yield, with the exception of *Big717* in the first crop. Ma-treatment plants showed a generally more vigorous growth at the vegetative stage than the others when water was not limited (Tables 1 and 2). Later on, during the induced water-stress period (flowering stage), these more sturdy plants consumed more water than the smaller plants in the other treatments. This may have led to the Ma plants being subjected to more severe water shortage (i.e., drought tress) than the plants in the other treatments and hence producing considerably lower yield.

It can be concluded here that well-grown plants that require larger quantities of water to keep the biomass alive will react more sensitively to drought stress during the flowering stage than plants with smaller biomass at that stage, leading to reduced grain yields.

3.3 Total Aboveground Biomass

For the total aboveground biomass, there were no significant differences between cultivation practices, but between *Suwan5* and the two hybrids (Table 5). Within the varieties, plants tended to produce the same amount. The open pollinating variety, *Suwan5*, gave the lowest total aboveground biomass for all treatments.

3.4 Harvest Index (HI)

The harvest index (HI) – the ratio of grain yield to total aboveground biomass – reflects the efficiency of a plant to translocate assimilated carbohydrates from the vegetative parts to the grains. The two hybrids were clearly more efficient than the open pollinating variety (Table 6), with *Big717* > *Big949* > *Suwan5*. Within-variety differences were only observed with *Suwan5* and *Big949*. For both varieties, HI was consistently lowest with the Ma treatment (manure application). This supports the observations and conclusions made for grain yield (see Table 3). HI was highly correlated with the grain yield in all treatments.

4 Conclusions

The open-pollinating variety *Suwan5* gave the lowest grain yield and the lowest total aboveground biomass. The single hybrid *Big717* produced the overall highest grain yields and the lowest vegetative aboveground biomass. The variety *Big949* produced high biomass, but under drought stress at the flowering stage the high moisture requirements of the plants could not be met and grain filling was reduced leading to low yields.

Within the varieties, the same effect was observed for the Ma treatment. Plants grew faster and produced higher biomass at the flowering stage when moisture stress was

Table 4: Grain yields of the tested varieties in relation to cultivation practices.

Cultivation practice *	*First crop*				*Second crop* ‡			
	Grain weight (g/plant) †			*Practice mean* ‡	*Grain weight (g/plant)* †			*Practice mean* ‡
	Suwan5	*Big717*	*Big949*		*Suwan5*	*Big717*	*Big949*	
CT	77.1 ^{a}	96.9	99.8 ^{a}	91.3 ^{ab}	21.1 ^{a}	57.1	25.7 ^{b}	34.3 ^{ab}
Mn	62.9 ^{ab}	102.1	90.3 ^{ab}	85.1 ^{bc}	2.9 ^{b}	58.7	35.7 ^{ab}	32.4 ^{ab}
Mi	69.8 ^{a}	107.8	92.7 ^{ab}	89.6 ^{ab}	1.4 ^{b}	57.6	28.2 ^{b}	28.0 ^{b}
Ma	45.1 ^{b}	110.1	83.9 ^{b}	79.7 ^{c}	1.2 ^{b}	39.2	5.2 ^{c}	16.0 ^{c}
PI	74.3 ^{a}	109.4	97.7 ^{a}	93.8 ^{a}	30.9 ^{a}	50.3	49.0 ^{a}	42.7 ^{a}
Variety mean §	65.5 ^{C}	105.2 ^{A}	92.9 ^{B}		12.2 ^{C}	52.2 ^{A}	27.6 ^{B}	
Statistical analysis ¶								
Practice	0.023	NS	NS	0.012	0.000	NS	0.001	0.002
Variety	-	-	-	0.000	-	-	-	0.000
Block	NS	NS	NS	NS	NS	NS	NS	NS
Practice × Variety	-	-	-	0.015	-	-	-	NS

* CT: conventional cultivation practice (removed residues); Mn: mungbean residue incorporated; Mi: spineless mimosa (*Mimosa invisa*) live mulch, intercropped; Ma: cattle manure incorporated; PI: mulching with commercial plastic sheeting.
Values in †,‡,§ followed by the same letters or with no letters are not significantly different according to LSD test at $P \leq 0.05$; † Mean comparison within varieties in each column, ‡ Mean comparison between practices; § Mean comparison between varieties; ¶ Values show significant levels. NS: non-significant at $P > 0.05$

Table 5: Total aboveground biomass of the tested varieties in relation to cultivation practices.

Cultivation practice *	*First crop*				*Second crop* ‡			
	Total aboveground biomass (g/plant) †			*Practice mean* ‡	*Total aboveground biomass (g/plant)* †			*Practice mean* ‡
	Suwan5	*Big717*	*Big949*		*Suwan5*	*Big717*	*Big949*	
CT	216.9	244.0	238.1	233.0	178.9 ^{a}	189.7	191.5	187.5
Mn	209.3	236.0	247.0	230.7	182.2 ^{a}	203.3	189.4	191.1
Mi	217.4	254.2	235.2	233.6	134.4 ^{c}	191.2	201.7	174.8
Ma	211.3	255.5	254.9	240.6	140.3 ^{bc}	211.9	196.0	183.5
Pl	205.2	253.0	243.9	234.0	170.2 ^{ab}	193.2	204.3	189.2
Variety mean §	210.8 ^{B}	248.5 ^{A}	243.8 ^{A}		161.9 ^{B}	197.8 ^{A}	195.9 ^{A}	
Statistical analysis ¶								
Practice	NS	NS	NS	NS	0.015	NS	NS	NS
Variety	-	-	-	0.000	-	-	-	0.000
Block	NS	NS	NS	NS	NS	NS	NS	NS
Practice × Variety	-	-	-	NS	-	-	-	0.018

* CT: conventional cultivation practice (removed residues); Mn: mungbean residue incorporated; Mi: spineless mimosa (*Mimosa invisa*) live mulch, intercropped; Ma: cattle manure incorporated; Pl: mulching with commercial plastic sheeting.
Values in †,‡,§ followed by the same letters or with no letters are not significantly different according to LSD test at $P \leq 0.05$; † Mean comparison within varieties in each column, ‡ Mean comparison between practices; § Mean comparison between varieties; ¶ Values show significant levels. NS: non-significant at $P > 0.05$

Table 6: Harvest index of the tested varieties in relation to cultivation practices.

Cultivation practice *	*First crop*				*Second crop* ‡			
	Harvest index (HI) †			*Practice mean* ‡	*Harvest index (HI)* †			*Practice mean* ‡
	Suwan5	*Big717*	*Big949*		*Suwan5*	*Big717*	*Big949*	
CT	0.32 ^{a}	0.40	0.43 ^{a}	0.38 ^{a}	0.12 ^{b}	0.30	0.13 ^{b}	0.18 ^{ab}
Mn	0.26 ^{ab}	0.44	0.39 ^{a}	0.36 ^{a}	0.02 ^{c}	0.28	0.19 ^{ab}	0.16 ^{b}
Mi	0.31 ^{a}	0.43	0.40 ^{a}	0.38 ^{a}	0.01 ^{c}	0.30	0.14 ^{b}	0.15 ^{b}
Ma	0.20 ^{b}	0.44	0.33 ^{b}	0.32 ^{b}	0.01 ^{c}	0.19	0.03 ^{c}	0.08 ^{c}
Pl	0.36 ^{a}	0.44	0.40 ^{a}	0.40 ^{a}	0.18 ^{a}	0.26	0.24 ^{a}	0.22 ^{a}
Variety mean §	0.29 ^{C}	0.43 ^{A}	0.39 ^{B}		0.07 ^{C}	0.26 ^{A}	0.14 ^{B}	
Statistical analysis ¶								
Practice	0.028	NS	0.025	0.002	0.000	NS	0.000	0.000
Variety	-	-	-	0.000	-	-	-	0.000
Block	NS	NS	NS	NS	NS	NS	NS	NS
Practice × variety	-	-	-	0.024	-	-	-	0.053

* CT: conventional cultivation practice (removed residues); Mn: mungbean residue incorporated; Mi: spineless mimosa (*Mimosa invisa*) live mulch, intercropped; Ma: cattle manure incorporated; Pl: mulching with commercial plastic sheeting.
Values in †,‡,§ followed by the same letters or with no letters are not significantly different according to LSD test at $P \leq 0.05$; † Mean comparison within varieties in each column, ‡ Mean comparison between practices; § Mean comparison between varieties; ¶ Values show significant levels. NS: non-significant at $P > 0.05$

introduced; this led to lower yields due to the higher water requirement, especially with *Suwan5* (both crops) and *Big949* (second crop). Those well-grown plants displayed a significant delay in silking thus increasing the tasseling-silking interval (TSI). These plants therefore had a higher incidence of abortion during the reproductive stage, and hence produced lower grain yields.

The study showed that the effects of cultivation practices on grain yield were less prominent than the variety effects. Moreover, some of the practices, particularly Ma, even had a negative effect on the yield. Therefore, variety selection is still a potential management tool that can effectively control the effects of drought stress on the plants. However, this is the results from the treatments over water stress occurring only during flowering stage and the degree of water stress was high (wilting point). Further studies are therefore highly recommended for the investigation of plant responses to drought-stress periods during other growth stages and with different degrees of drought stress. On-farm trials under uncontrolled drought-stress conditions should be also carried out to confirm the results of the on-station experiment.

Acknowledgement
The authors thank the Danish Development Assistance (Danida) for funding the study.

References

ÇAKIR, R.; Effect of water stress at different development stages on vegetative and reproductive growth of corn; *Field Crops Research*; 89:1–16; 2004.

CHIVENGE, P., DIMES, J., NHAMO, N., NZUMA, J. K. and MURWIRA, H. K.; Evaluation of APSIM to simulate maize responses to manure inputs in wet and dry regions of Zimbabwe; in: *Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa*, edited by BATIONO, A.; 85–91; Centro Internacional de Agricultura Tropical - CIAT, Cali, Colombia; 2004.

CHO, K. M.; *Land-use and soil-quality dynamics in an agricultural area of Nakhon Ratchasima Province, Northeast Thailand*; Doctoral dissertation; Asian Institute of Technology; Pathumthani, Thailand; 2003.

CHOTECHAUNGMANIRAT, S.; Role of thornless mimosa, *Mimosa invisa*, in improving soil productivity in corn production; Proposal for the Best Research Award by the National Research Council of Thailand; The National Maize and Sorghum Research Center, Kasetsart Universit, Bangkok, Thailand; 1997.

DOORENBOS, J. and KASSAM, A. K.; Yield response to water; Irrigation and Drainage Paper 33; FAO, United Nations, Rome; 1979.

GINTING, D., MONCRIEF, J. F., GUPTA, S. C. and EVANS, S. D.; Corn yield, runoff, and sediment losses from manure and tillage systems; *J. Environ. Qual.*; 27:1396–1402; 1998.

MANUPEERAPAN, T. and GRUDLOYMA, P.; Corn (*Zea mays* L.); in: *A guide book for field crop production in Thailand*; 9–18; Field Crops Research Institute, Department of Agriculture, Ministry of Agriculture and Cooperatives; 2001.

MUSICK, J. T. and DUSEK, D. A.; Irrigated corn yield response to water; *Trans. ASAE*; 23:92–103; 1980.

NeSmith, D. S. and Ritchie, J. T.; Short- and long-term responses of corn to a pre-anthesis soil water deficit; *Agron. J.*; 84:107–113; 1992.

Parham, J. A., Deng, S. P., Raun, W. R. and Johnson, G. V.; Long-term cattle manure application in soil. I. Effects on soil phosphorus levels, microbial biomass C, and dehydrogenase and phosphatase activities; *Biol. Fertil. Soils*; 35:228–337; 2002.

Ribaut, J. M., Gonzalez-De-Leon, D., Deutsch, J., Edmeades, G., Huerta, E. and Hoisington, D.; Genetic dissection of the drought-induced anthesis-silking interval (ASI) in tropical maize; International Plant Genome (III) Conference, San Diego, CA; 1995.

Sommerfeldt, T. G. and Chang, C.; Changes in soil properties under annual applications of feedlot manure and different tillage practices; *Soil Sci. Soc. Am. J.*; 49:983–987; 1985.

Sutton, A. L., Nelson, D. W., Kelly, D. T. and Hill, K. L.; Comparison of solid vs. liquid dairy manure applications on corn yield and soil composition; *J. Environ. Qual.*; 15:370–375; 1986.

Wickens, G. E.; Ecophysiology of economic plants in arid and semi-arid lands; in: *Adaptation of desert organisms*, edited by Cloudsley-Thompson, J. L.; 123–130; Springer-Verlag, Berlin Heidelberg; 1998.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 106, No. 1, 2005, pages 29–39

Evaluation of Nematicidal Action of Some Botanicals on *Meloidogyne incognita* In Vivo and In Vitro

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Abstract
Eggmasses or larvae of *Meloidogyne incognita* were exposed to varying concentrations of neem leaf (fresh and dry), *Borelia* sp., groundnut leaf and garlic bulb. Neem leaf and garlic bulb extracts inhibited hatching of eggmasses and were lethal to larva. A comparative study of neem and garlic bulb extracts prepared at 20% concentration and applied weekly at 25 ml per pot were carried out in the screenhouse. Each pot filled with 2 kg of pasturised soil was inoculated with 2 000 larvae of *M. incognita* by introducing 500 g of infested soil from tomato culture raised in the screenhouse. These extracts significantly reduced root-knot infection indices on tomato when compared to the control. However, garlic extract demonstrated greater potential than neem leaf extract in the control of root-knot infection of tomato in vivo.

Keywords: *Meloidogyne incognita*, neem leaf, garlicbulb, *Borelia* sp., extracts, botanicals

1 Introduction

The use of botanical extracts for controlling *Meloidogyne* is becoming appealing because of the growing problem of environmental pollution arising from the use of persistent pesticides. There has been a de-registration of some hazardous nematicides. Increasing pressure is on farmers to use non-chemical pest control methods that do not pollute the environment. This emphasis the need for new methods of control such as the use of plant extracts. Efficacy of various plant extracts in nematode control has been studied (Akhtar, 1999; Kali and Gupta, 1980; Mukherjee and Sukul, 1978; Netscher and Sikora, 1990; Rossner and Zebitz, 1986). Nematicidal effect of garlic has been reported, but was phytotoxic. Water extracts of some Indian plants and neem leaf were nematicidal on root-knot nematodes and *Pratylenchus* sp. respectively (Mukherjee and Sukul, 1978; Egunjobi and Afolami, 1976). Studies on the identification and use of local plant materials for the control of nematodes, or integrated with other methods of control, are current areas of research in plant nematology . The objective of this study was to (i) evaluate the effect of some botanicals on *M. incognita* (ii) compare the potentials of neem leaf and garlic extracts for the control of root-knot (*Meloiddogyne incognita*) in tomato.

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2 Materials and Methods

2.1 Effect of Extracts of Fresh and Dry Neem Leaves

Fresh neem leaf and dry neem leaf extracts were obtained as follows: 0, 10, 20 and 30 grams of dry neem leaf or fresh neem leaf ground in a mortar were each added to 100 ml of water. The mixture was allowed to stand for four hours and filtered through a fine mesh sieve to remove the leaf debris. The filtrate was further passed through a Whatman No. 40 filter paper overlaid with a 2-ply silktex® tissue paper in a funnel to remove the chlorophyll with a view to having a clear extract of the filtrate. The filtrates were labeled as 0, 10, 20 and 30% concentration of either fresh or dry neem leaf extract.

Twenty *M. incognita* eggmasses were hand-picked with a pair of forceps and introduced into a watchglass to which 1.0ml of 0, 10, 20 or 30% fresh or dry neem leaf extract was applied. Each watchglass with 20 eggmasses received only one concentration level of either fresh neem leaf extract or dry neem leaf extract. Each treatment was replicated three times and the replicates arranged in a completely randomized design on a laboratory bench at a room temperature of between 25 and 27 °C.

The treatments were observed for egg hatchability over a period of 24 hours. After 24 hours, all unhatched eggmasses from each treatment were picked and transferred into a watch glass containing 1.0 ml of tap water. The eggmasses were pierced open and observed for live larvae of *M. incognita*.

Another set of watchglasses containing 20 larvae per watchglass were treated with 1.0 ml of either 0, 10, 20 or 30% neem leaf extract. Each watchglass with 20 larvae received only one concentration level of either fresh neem leaf or dry neem leaf extract at a time. Each treatment was replicated three times and arranged in a completely randomized design on a laboratory bench and observed for larval mortality at 10 minutes interval for 4 hours starting from 10 am.

2.2 Effect of Leaf Extracts of Borelia sp., Groundnut and Garlic

Twenty grams each of fresh leaves of *Borelia* sp. *Borelia* flowers, groundnut leaves and garlic bulb were pounded in a mortar and transferred into a beaker to which 100 ml of water was added. The mixtures were allowed to stand for four hours after which they were filtered through a fine mesh sieve to remove debris. With the exception of garlic, the filtrate was further passed through a Whatman No. 40 filter paper overlaid with a 2-ply silktex® in a funnel to remove chlorophyll.

Twenty *M. incognita* eggamsses were hand-picked with a pair of forceps and introduced into a watchglass to which was added 1.0ml each of the extracts of the fresh leaves of either *Borelia* sp., *Borelia* flower, groundnut leaves or garlic bulb. A control treatment with tap water was included. Each treatment was replicated three times and arranged in a completely randomized design on a laboratory bench at room temperature of between 25 and 27 °C. The treatments were observed for egg hatchability over a period of 24 hours.

2.3 Comparison of Neem and Garlic Bulb on M. incognita In Vivo

Seedlings of wilt susceptible tomato cultivar: Roma VF, were raised on heat pasteurized soil. Three weeks old seedlings were transplanted into plastic (15 cm diameter) pots filled with 2.0 kg of pasteurized soil. Each treatment was inoculated with 2000 larvae of *M. incognita* introduced by adding to each pot 500 cm^3 of root-knot infested soil from tomato culture raised in the screenhouse. There were three tomato seedlings per pot. The fresh neem leaf and garlic bulb extracts were obtained by grinding 20 grams each of fresh neem leaves and garlic bulbs in a mortar to which were added 100 ml of water. The suspensions were allowed to stand for four hours and filtered through a fine mesh sieve to remove the leaf debris. One week after transplanting, 25 ml of the extracts were poured into the soil in the pot around the base of the tomato stem weekly for eight weeks. The experiment was terminated at 10 weeks after transplanting. All treatments were replicated three times.

The following parameters were determined: root weight and shoot weights were determined by carefully removing the plants from the pots and separating into roots and shoots. The fresh roots and shoots were weighed separately. The root-knot galling index was assessed on a scale of 1-10 as described by Bridge and Page (1980). The rating chart used by Bridge and Page (1980) for root galling is as follows:

0 ≙ no knots on roots
1 ≙ few small knots difficult to find
2 ≙ small knots only but clearly visible; main roots clean
3 ≙ some larger knots visible, but main roots clean
4 ≙ larger knots predominate but main roots clean
5 ≙ 50% of roots knotted; knotting on parts of main root system
6 ≙ knotting on some of main roots
7 ≙ majority of main roots knotted
8 ≙ all main roots knotted; few clean roots visible
9 ≙ all roots severely knotted; plant usually dying
10 ≙ all roots severely knotted; no root

The number of eggmasses per gram of root, number of eggs per eggmass and number of adult female per gram of root were assessed by direct counting technique (Daykin and Hussey, 1985). Roots were cut into pieces and thoroughly mixed. Using a Mettler balance, one gram of root was weighed out in three replications. The pieces of root were spread evenly in a grid petri-dish. Adult females and egg masses were counted in each square in the grid. From the one gram of root, three egg masses were randomly picked and transferred into a counting chamber. The eggmass was pierced open with a pair of sharp forceps and the numbers of eggs and larvae were determined. The mean of three replicates was recorded. In the absence of adult females and eggmasses in a root number of larvae per 10 g of root were determined. Roots were teased and allowed to stand over the Baerman's tray for 24 hours. The filterate was decanted into a beaker and nematode population counted over the microscope. Soil analysis for larval population was determined by the modified Cobb's decanting and sieving technique (Barker, 1985). The mean differences between treatment in terms of root-knot infection indices

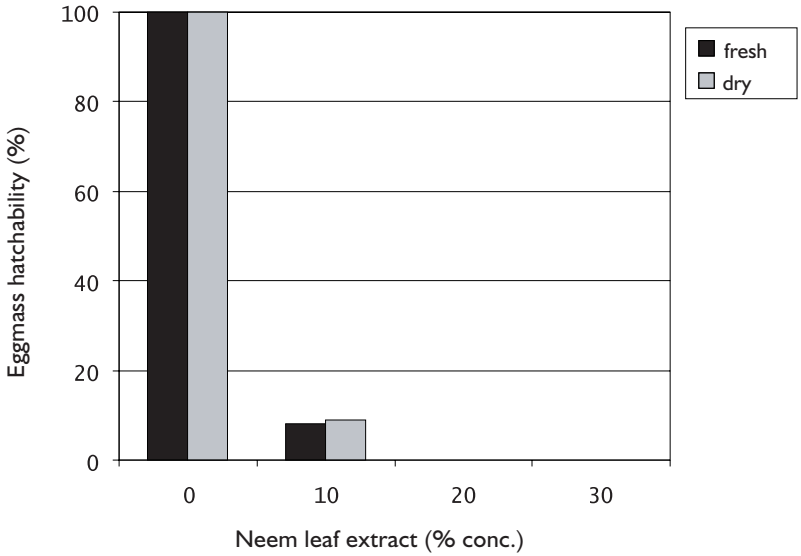
were determined by a non-parametric test of significance, employing the Kruskal-Wallis One Way Analysis of Variance as used by HARRIS and FERRIS (1991), whereas the mean differences of shoot and root weights between treatments were determined by the conventional ANOVA.

3 Results

3.1 Effects of Extracts of the Botanicals on Meloidogyne incognita In Vitro

Every eggmass of *M. incognita* in the control treatment hatched. Hatching commenced between 1-3 hours after exposure to water and was virtually complete after 24 hours. Eggmasses exposed to 20% and 30% concentration of neem leaf extract did not hatch. At 10% concentration of the neem leaf extract, an eggmass ruptured but the released larvae were all deed or moribund (Fig. 1). All unhatched eggmasses teased up contained dead or moribund larvae.

Figure 1: Effect of fresh and dry neem leaf extract on eggmass hatchability at 24 hours after exposure.



The larvae exposed to 20% and 30% concentrations of the fresh neem leaf extracts showed 50% and 90% mortality within 15 minutes of exposure respectively. By 30 minutes, mortality had reached almost 100% in contrast to about 10% mortality recorded in the control after 24 hours (Fig. 2). The effect of fresh neem extract on larval mortality was apparent immediately on exposure.

The dry neem leaf extract caused initial death of larvae only after 30 minutes of exposure to the highest concentration of 30% (Fig. 3). At 10% concentration of the extract, mortality was as low as one larva after 3 hours of exposure. However, after 24 hours of

Figure 2: Effect of fresh and dry neem leaf extract on eggmass hatchability at 24 hours after exposure.

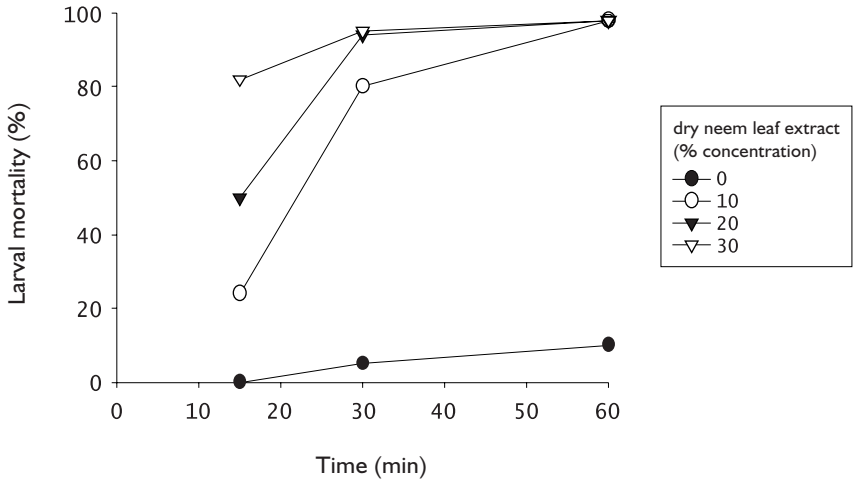
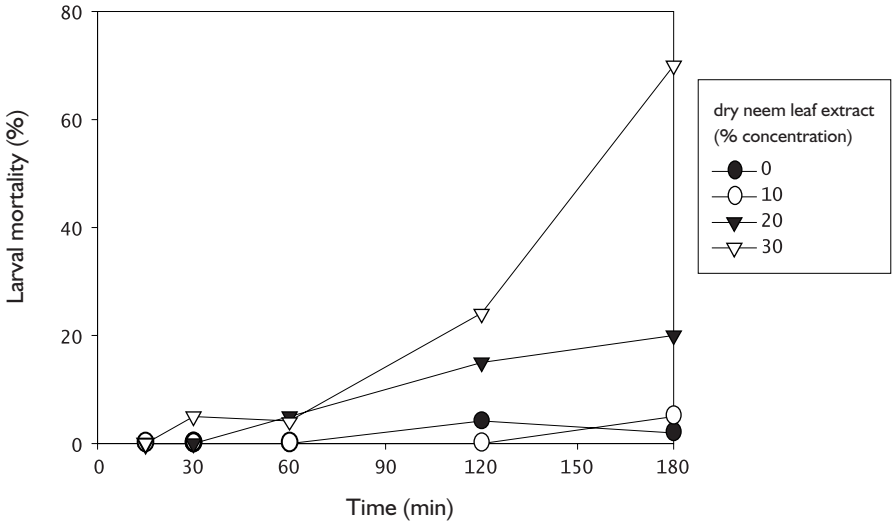


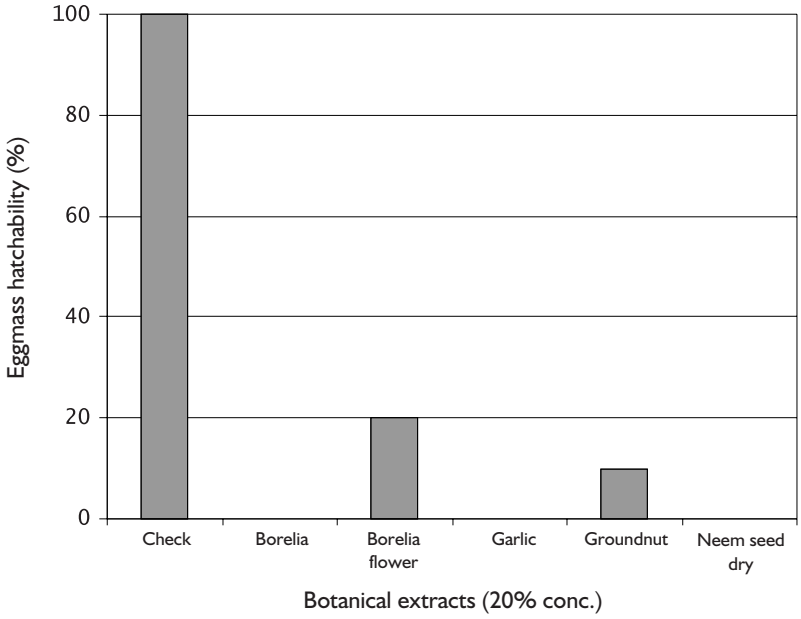
Figure 3: Effect of fresh and dry neem leaf extract on eggmass hatchability at 24 hours after exposure.



exposure all treatment levels of dry leaf extract caused 100% mortality of larvae except in the control where 85% of larvae remained alive. The cumulative effect of the extracts of dry and fresh neem leaves on mortality of larvae and hatchability of eggmasses was similar after 24 hours of exposure regardless of the concentrations of the extracts.

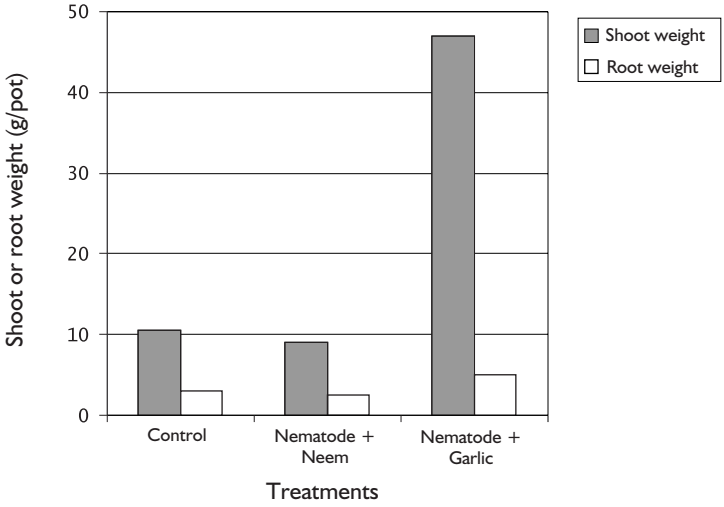
In *Borelia* sp. Flower and groundnut leaf extracts initial hatching of eggmasses occurred after 3 hours of exposure to the extracts in contrast to water where hatching occurred within an hour of exposure (Fig.4). At the end of 24 hours, 100% hatching of of eggmasses occurred in water in contrast to eggmasses exposed to Borelia flower and groundnut leaf extracts where less than 25% of the eggmasses hatched. There was no hatching when the eggmasses were exposed to Borelia leaf extracts (Fig. 4). The larvae in unhatched eggmasses exposed to Borelia flower and groundnut leaf extracts remained motile, while those exposed to Borelia leaf extract were dead or moribund.
Garlic extracts completely inhibited the hatching of eggmasses. All larvae from eggmasses teased open were dead or moribund (Fig. 4).

Figure 4: Effect of fresh and dry neem leaf extract on eggmass hatchability at 24 hours after exposure.



Root and shoot weight differed significantly among treatments, with garlic giving the highest root and shoot biomass (Fig. 5). It was observed that first flowering occurred at 5 WAT, and by the sixth week there was 100% flowering in pots treated with neem leaf and garlic extracts. Root galling index decreased significantly in pots treated with garlic extract. Neither eggmass nor female was obtained from pots treated with garlic

Figure 5: Effect of fresh and dry neem leaf extract on eggmass hatchability at 24 hours after exposure.



extract. There was no significant differences in root galling index between the control and those treated with neem leaf extract. However, eggmass and females per gram of root decreased significantly in neem leaf treated pots compared to the control (Table 1). Similarly, final larval population was significantly lower in garlic and neem leaf treated pots than the control pots. There were, however, larval penetrations of roots but only the second stage larvae were extracted (10 larvae per 10 g of root).

Table 1: fect of neem leaf and garlic extracts on *M. incognita* infection indices on tomato (Roma VF) under screenhouse conditions.

Treatment	*Root-knot galling index*	*Eggmass per gram root*	*Female per gram root*	*Larval population/ per 500* cm^3
Control	7.0^a	43.0^a	45.0^a	1048^a
Nematode + Neem	7.0^a	18.0^b	18.0^b	180^b
Nematode + Garlic	2.0^b	0.0^c	0.0^c	140^b
Signficance level	0.05	0.02	0.02	0.03

Means followed by the same letter in a column are not significantly different ($P = 0.05$) as determined by Kruskal Wallis One Way Analysis of Variance.

4 Discussion

In the present study, there was a complete inhibition of hatching of larvae when fresh eggmasses of *M. incognita* were exposed to neem leaf extracts. A shorter time span was needed for fresh neem leaf extract to obtain similar result as dry neem leaf extract. The initial slow response of larvae to extract of dry neem leaf compared to the fresh leaf is probably due to the slower diffusion of active ingredients into the solution from the dry neem leaves relative to the fresh leaves. Active ingredients in fresh neem leaf extract would more readily diffuse into the water than dry neem leaf extract given the same time span. Hence, after 24 hours the same level of mortality was obtained for both dry and fresh neem leaf extract.

Earlier work in Western Nigeria by EGUNJOBI and AFOLAMI (1976) reported the toxicity of water soluble extracts of neem leaf to *Pratylenchus brachyurus*. Aqueous extracts of leaf, flower, fruit, bark, root and gum of neem were reported to be highly toxic to nematodes with fruit extract showing the most leathal activity followed by leaf extract (PARMAR, 1987). The inability of the eggmass to hatch is as a result of ingress of plant extracts into the eggmass. Larvae in the eggmass were exposed to the toxic effect of the extract resulting first in reduced mobility and finally death or moribund state. Once this state is reached the larva cannot pierce through the wall with its stylet hence hatching ceases. The eggmass which is a part of the perineal region of the femal in root-knot is permeable to the active ingredient in the extracts (HIRSCHMANN, 1985).

Less than 25% of the eggmasses were hatched in the extracts of Borelia flower and groundnut leaf. Furthermore, unhatched eggs contained motile larvae, suggesting that substance in the Borelia flower and groundnut leaves did not inhibit hatching; rather they prolonged the time interval required for hatching. Groundnut plant is known to be resistant to species of *Meloidogyne* occurring in Nigeria (ADESIYUN *et al.*, 1990). Hatching of eggmasses exposed to groundnut leaf extract suggest that resistance of groundnut to root-knot in Nigeria is based on factors other than the presence of toxic substances in the root. Borelia leaf extract exhibited complete inhibition of hatching although extracts from the flower did dot.

The use of botanical extracts for controlling of *Meloidogyne* is appealing because of the growing problem of environmental pollution arising from the use of persistent pesticides like chlorinated hydrocarbons such as chloropicrin. Efficacy of various plant extracts in nematode control has been established. Water extracts of India plants, *Fleurya interrupta, Peritrophe bicalyculata and Andrographis paniculata* were nematicidal and resulted in 100% mortality of root-knot larvae within 40 minutes (MUKHERJEE and SUKUL, 1978). Nematicidal properties of tagetes and wild marigold (TOIDA and MORIYAMA, 1978), *Emblica officinalis* and *Carrissa curandas* (HASEEB *et al.*, 1980) against root-knot larvae have been reported.

Efficacy of plant extracts, however, depends on its concentration and the duration of exposure of the nematode to the extract (MAHMOOD *et al.*, 1979; KALI and GUPTA, 1980). Concentration of active ingredients in neem seed and leaf extracts may differ depending on the environmental condition, the year of collection and geographical area

of the neem trees (Zongo *et al.*, 1993). However, their aqueous extracts appear to contain some nematicidal compounds which tend to inhibit the hatching of eggmass and are directly toxic to *M. incognita* larvae.

In the present study, garlic bulb extract gave significant reduction in root-knot nematode galling index, and root and soil larval populations. The garlic extract showed no phytotoxicity in this study in contrast to some reports of phytotoxicity of garlic extracts to some crop plants (Sukul *et al.*, 1974). Most reports on the use of garlic and neem leaf extracts in nematode control used high application rates and concentrations. (Egunjobi and Afolami, 1976) used 200 ml of 50% of concentration of neem leaf extract per plant to control *Pratylenchus brachyurus* while, Sukul *et al.* (1974) used 250 ml of 50% concentration of garlic extract per plant. These application rates are 8-10 times higher than the application rate of 25 ml of 20% concentration of neem and garlic extracts per plant used in this study. However, such unusually high concentrations may lead to osmotic loss of water from the root tissue resulting in wilting. The relatively low application rate, 25 ml of 20% concentration per plant, used in this study, appears effective against *M. incognita*. Garlic bulb extract was more effective than neem leaf extract as evidenced by the significant reduction in galling index and other reproductive factors such as eggmass/g and number of females/g of root. The results were similar to the findings of Sukul *et al.* (1974) on tomato, that garlic extract was highly effective in reducing root-knot infection. The garlic extract might have been highly lethal to the nematode larvae. The extract probably acted directly on the infective second stage larvae in the soil, thus reducing the number of motile larvae available to penetrate the tomato roots.

Although root-knot galling index was similar in the neem treated and untreated control, the reduction in number of eggmasses, number of females and final larval population of the soil is a strong indication of the ability of neem leaf extract to control root-knot nematode in tomato. Galling and reproductive responses are more reliable indicators of host plant reaction than just root-knot galling index (Fassuliotis, 1985).

The inability of the control plants to flower is probably due to the combined action of the nematode and inadequate availability of nutrients (Netscher and Sikora, 1990). The present study did not record any significant increase in growth among plants treated with aqueous neem leaf extract compared with the control. This is probably due to the low application rate used. Increases in plant growth parameters with aqueous neem extracts have been reported (Egunjobi and Afolami, 1976; Rossner and Zebitz, 1986), and the growth rate depended on the application rate (Kali and Gupta, 1980). Therefore, whereas the low application rate used in this study seemed to give a measure of control of *M. incognita*, plant growth was, however, not affected. Therefore, the productivity of the neem treated plants must be improved by supplementary inorganic fertilizer application or by increasing the application rate. This study shows that garlic has high potentials for nematode control. This, however, needs to be demonstrated under varying field conditions in the savanna.

References

Adesiyun, S. O., Caveness, F. E., Adeniji, M. O. and Fawole, B.; Nematode Pests of Tropical Crops; chap. 3; Heinemann Educational Books Nigeria Limited; 1990.

Akhtar, M.; Plant growth and nematode dynamics in response to soil amendments with neem products, urea and compost; *Bioresource Technology*; 69:181–183; 1999.

Barker, K. R.; Nematode extraction and bioassays; in: *An Advanced treatise on Meloidogyne: Vol. 11, Methodology*, edited by Sasser, J. N. and Carter, C. C.; chap. 2; North Carolina State University Department, Dept. of Plant Pathology and the United States of Agency for International Development, Raleigh; 1985.

Bridge, J. and Page, S. L. J.; Estimation of root-knot nematode infestation levels on roots using a rating chart; *Tropical Pest Management*; 26:296–298; 1980.

Daykin, M. E. and Hussey, R. S.; Staining and Histopathological techniques in Nematology; in: *An Advanced treatise on Meloidogyne: Vol. 11, Methodology*, edited by Sasser, J. N. and Carter, C. C.; chap. 3; North Carolina State University Department, Dept. of Plant Pathology and the United States of Agency for International Development, Raleigh; 1985.

Egunjobi, O. A. and Afolami, S. O.; Effects of Neem (*Azadirachta indica*) leaf extracts on population of *Pratylenchus brachyurus* and on the growth and yield of maize; *Nematologica*; 22:125–132; 1976.

Fassuliotis, G.; The role of nematologist in the development of resistant cultivars; in: *An Advanced treatise on Meloidogyne: Vol. 11, Methodology*, edited by Sasser, J. N. and Carter, C. C.; chap. 20; North Carolina State University Department, Dept. of Plant Pathology and the United States of Agency for International Development, Raleigh; 1985.

Harris, A. R. and Ferris, H.; Intgeraction between *Fusarium oxysporum f. sp. trachiephilum* and *Meloidogyne* spp. in *Vigna unguiculata*. 1. Effects of different inoculum densities on Fusarium wilt; *Plant pathology*; 40:445–456; 1991.

Haseeb, A., Singh, B. and Khan, A. M.and Saxena, S. K.; Effect of watering and mode of application of oil cakes and nematodes on their efficiency in controlling root-knot nematode on tomato; *Acta Botanica Indica*; 8:193–195; 1980.

Hirschmann, H.; The classification of the family Meloidogynidae; in: *An Advanced treatise on Meloidogyne: Vol. 11, Methodology*, edited by Sasser, J. N. and Carter, C. C.; chap. 4; North Carolina State University Department, Dept. of Plant Pathology and the United States of Agency for International Development, Raleigh; 1985.

Kali, R. and Gupta, D. C.; A note on the efficiency of fresh neem leaf extract in the control of *Meloidogyne javanica* infecting chickpea; *Indian Journal of Nematology*; 10:96–98; 1980.

Mahmood, I., Masood, A. and Saxena, S. K. adn Hussain, S. I.; Effect of some plant extracts on the mortality of *Meloidogyne incognita* and *Rotylenchulus reniformis*; *Acta Botanica Indica*; 7:129–132; 1979.

Mukherjee, S. N. and Sukul, N. C.; Nematicidal action of three species of wild herb; *Indian Journal of Research*; 2:12; 1978.

Netscher, C. and Sikora, R. A.; Nematode parasites of vegetables; in: *Plant Parasitic Nematode in Subtropical and Tropical Agriculture*, edited by Luc, M., Sikora, R. A. and Bridge, J.; chap. 7; C.A.B. International; 1990.

Parmar, B. S.; An overview of Neem Research and use in India during the years 1983-1986; in: *Natural Pesticides from the Neem Tree and other Tropical Plants; Proccedings of the 3rd Int. Neem Conference, Nairobi (1996)*, edited by Schmutterer, H. and Ascher, K. R. S.; 55–80; GTZ Eschborn, Germany; 1987.

Rossner, J. and Zebitz, C. P.; Effect of neem products on nematodes and growth of tomato (*Lycopersici esculentum*) plants; Proceedings of the third Intenational Neem Conference, Nairobi, pp.611-621; 1986.

Sukul, N. C., Das, P. K. and De, G. C.; Nematicidal action of some edible crops; *Nematologica*; 20:187–191; 1974.

Toida, Y. and Moriyama, H.; Effects of the Marigold on the control of nematodes in Mulberry. 2. Nematicidal effects of the Mexican marigold by application; Helminthological Abstract Series B. 49; Abstract 696; 1978.

Zongo, J. O., Vincent, C. and Stewart, R. K.; Effects of neem seed kernal extracts on egg and larval survival of the sorghum shot fly, *Atherigona soccata* Rondani (Dipter Muscidae); *Journal of Applied Entomology*; 115:363–369; 1993.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 106, No. 1, 2005, pages 41–48

Evaluation of Botanical Mixtures for Insect Pests Management on Cowpea Plants

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Abstract
Studies were conducted at the Research Farm of the Institute for Agricultural Research, Zaria in 1999 and 2000 rainy seasons to evaluate the efficacy and synergistic activity of extracts mixtures from herbal landraces in reducing pests numbers on cowpea plants and ensuring high yield of grains. The extracts mixed in a ratio 10:10 % w/w included: cashew nutshell + garlic bulb; cashew nutshell + African pepper and garlic bulb + chilli pepper. The results indicated that all the herbal extract mixtures reduced the numbers of the tested insect pests (legume flower bud thrips, legume pod borer larvae and pod sucking bugs) and pod damage as well as increased grain yields by 4 - 5 times compared to the untreated control in the two years of investigation. The synergistic advantage of mixing two different plant species in botanical formulations could play a key role in the renewed effort to control pests of agricultural crops using biopesticides.

Keywords: extracts, mixtures, synergism, management, insect pests, cowpea, biopesticides

1 Introduction

Plant based insecticides (PBI) have been used for many centuries (Jacobson, 1958, 1975) among limited resource farmers in developing countries to control insect pests of both field crops and stored produce, but their potential was initially limited and ignored. Nicotine, rotenone and pyrethrum were popular among the PBIs used to some extent for storage pests control and other pests in green houses (Schmutterer, 1981). Some of these plant species possess one or more useful properties such as repellency, antifeedant, fast knock down, flushing action, biodegradability, broad-spectrum of activity and ability to reduce insect resistance (Olaifa *et al.*, 1987; Stoll, 1988). However, most of them are either weak insecticidally or may require other plant species with different mode of action (depending on the ratio and rate of application) to increase their potency (Sommers, 1983; Oparaeke, 2004). For instance, *Xylopia aethiopica* (Dunal) (A. Rich.) is found to be weak insecticidally for control of *Callosobruchus maculatus* Fab. on bruchid (Oparaeke, 1997; Oparaeke and Bunmi, 2004) and on field pests of cowpea (Oparaeke, 2004). However, ground, dried fruit of *X. aethiopica* (African pepper or

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Ethiopian pepper) mixed with chillies (*Capsicum spp.*) and applied to kola nuts was found to have repellent properties against kola weevils (BURKILL, 1985). Extracts of chilli pepper in mixture with garlic (*Allium sativum* L.), onion (*Allium cepa* L.) bulbs extracts and lemon grass (*Cymbopogon citratus* Staph.) leaf extract were found very effective against some leaf eating insect pests of crops (STOLL, 1988). In South East Asia, rice farmers are said to use a mixture of chilli pepper, dried tobacco leaves, Tubli root, and *Croton tiglum* against stem borers (ANONYMOUS, 1977). In the Philippines, farmers have been reported using a mixture of *Derris* roots, seeds of *Jatropha curcas* and *Barringtonia asiatica* to control *Leptocorisa* acuta on rice (BLAUW, 1986 in STOLL (1988).

In South Eastern Nigeria, rural farmers mix chilli pepper and wood ash of *Parkia* spp., *Elaeis guineensis*, *Eucalyptus* spp. or *Azadirachta indica* (A. Juss) to control *Podagrica* sp. on okra plants, *Abelmoschus esculentus* L. AMADI, A. O., 1993, personal communication). The natives in this area also use the mixture of *Chromolaena odorata* L. and *Ocimum gratissimum* L. leaf extracts to repel termites, "tailor ants" and "soldier ants" around their houses. Similarly, an admixture of water from fermented cassava (*Manihot esculentus* Crantz) tubers and bitter leaf (*Vernonia amygdelina* L.) has shown potency against "tailor ants" infesting local pear fruits and leaves in eastern Nigeria. Since there is paucity of documented information on the use of plant extract mixtures in pest control, this study was aimed at assessing the efficacy of mixtures of plant extracts for management of pests of cowpea plants.

2 Materials and Methods

Field trials were conducted in 2000 and 2001 cropping seasons under rain fed conditions on the Research Farm of the Institute for Agricultural Research, Samaru (Lat. 11° 11' N and 07° 38' N) in the northern Guinea Savanna of Nigeria. The rainy season commences in June and lasts till October (first or second week). The amount and distribution of rainfall vary from year to year usually between 150 to 350 mm per annum. Temperatures during the period varied from 25 - 32 °C and in the dry harmattan, harvest period (November - December) the temperature fluctuated from 24 - 18 °C. The soil type is clay-loam with organic matter content less than 0.02 %. The colour of the topsoil varies from light brown to dark brown and the pH ranges from 6.5 - 8.5. The field used for this study had an area of 0.4 ha and was incorporated into the crop rotation (cereals/legumes) management system of the farm. The field was first sprayed with glyphosate (one liter per hectare) post emergent to control grasses and sedges and some broad leaf and creeping weeds. After three weeks, the field was then disc harrowed and ridged.

The layout consisted of five ridges per plot (three main ridges and two discard ridges, one on either side of the main ridges) spaced at 0.75 m apart. Each plot size was 18.75 m^2 (gross) and was separated by a 1.5 m wide border margin on all sides. The materials used included a mixture of cashew nutshell + garlic bulb, cashew nutshell + African pepper (*X. aethiopica*), chilli pepper + garlic bulb. These were purchased from the local market in Samaru and mixed at 10:10 % w/w. There were a synthetic insecticide and

untreated control checks and all the treatments were replicated three times. The plots were arranged in a randomized complete block design.

SAMPEA 7, cowpea variety seeds dressed with Apron plus (1 sachet / kg seed) were sown three seeds per hole at 0.2 m apart in the first week of August in both years. A mixture of Galex (metalachlor 250 g a.i. and metobromuron 250 g a.i.) and Gramoxone (paraquat) was applied at a rate of 2.5 kg a.i./ha immediately after sowing to control weeds. The seedlings were thinned to two plants per stand at two to three weeks after sowing (WAS). Compound fertilizer (NPK 15:15:15) was applied as side dressing at the rate of 37.5 kg a.i./ha. Four WAS, the plants received a tank mixture of Benlate (benomyl) and Dithane M45 (mancozeb) at 0.33 kg a.i. /ha to control fungal diseases. Fresh materials (500 g or 10 % w/w) of cashew nutshell, garlic bulb, African pepper were weighed separately into a wooden mortar and pounded while only 2 % chilli pepper was used due to its phytotoxicity at higher rates. The pounded materials were mixed in different buckets according to their respective treatments and 3.5 litre hot water (60 $^{\circ}$C) was added to each bucket, thoroughly stirred and allowed to stand overnight. The solutions were filtered with muslin cloth using 1.0 litre hot water. A 250 ml solution of 20 % w/v starch and bar soap each was added to the extracts and stirred. The buckets were labeled and taken to the field for spraying.

Field applications of extract mixtures and Uppercott (Cypermethrin + Dimethoate at 250 g a.i./ha. each) commenced at 7 WAS which coincided with the period of onset of flowers in this cowpea variety. Spraying started from 10.00 a.m to 12.00 p.m each day after insects sampling using a CP-3 Knapsack sprayer. All the pesticides were sprayed once every week for four weeks and whenever it rained within two hours of spraying, the extract mixtures were re-sprayed the next day.

Insect pests sampling was taken from 6.30 a.m to 9.30 a.m every seven days. Flower bud thrips (*Megalurothrips sjostedti* Trybom) and legume pod borers (*Maruca vitrata* Fab.) were sampled by random picking of 20 flowers from plants in each plot. The flowers were placed in vials containing 30 % alcohol and taken to the laboratory where they were dissected the next day and the number of each pest found was recorded. *M. vitrata* larvae were also assessed from 20 pods randomly picked from 10 plants in each plot. Assessment of both nymphs and adult coreid bugs (*Clavigralla tomentosicollis* Stal.) was based on visual observation of three plants randomly selected within three 1.0$\times$1.0 m quadrants, which were located randomly within the main ridges on each plot.

Pod density (a measure of efficacy of insecticide against thrips / borer larvae infestation on flowers) was assessed at 10 WAS by counting pods produced from a random sample of 10 plants per plot. Pod damage assessment involved counting the number of damaged pods per plant and dividing by the total number of pods produced per plant in a random sample of 10 plants per plot. These were expressed in percentages by multiplying by 100. Grain yield was recorded from threshed grains harvested from each plot. Ten plants were randomly inspected visually per plot for signs of phytotoxicity two days after each spraying.

All data were analyzed using Analysis of Variance (ANOVA) and treatment means were separated by Student Newman Keuls test at 5% (SAS Institute, 1989).

3 Results

In 2000 and 2001, the mean numbers of *M. sjostedti* in cashew nutshell + garlic bulb and chilli pepper + garlic bulb extracts were lower than the values in cashew nutshell + African pepper and cashew nutshell + West African black pepper extracts. Although, Uppercott (Cypermethrin + Dimethoate at 250 g a.i./ha. each) treatment recorded the lowest number of thrips in both seasons, the figures did not significantly differ from the first two extract mixtures. All the extract mixtures treatments had significantly ($P < 0.05$) lower thrips numbers than the untreated control (Table 1). *M. vitrata* numbers were lower in Uppercott treated plots but were not significantly lower than in the extracts mixtures treated plots. However, all the treated plots had significantly lower numbers of *M. vitrata* than in the untreated check in both seasons. Uppercott caused the highest reduction in pod sucking bugs infestation but did not perform better than plant extracts mixtures. However, the number of pod sucking bugs in cashew nutshell + African pepper, African pepper + bitter leaf extract mixtures were not significantly lower compared with the untreated control in both seasons (Table 1).

Table 1: Effects of botanical mixtures on pest's infestation on cowpea.

Treatment	*Mean number of insects 2000*			*Mean number of insects 2001*		
	Thrips / flower	*Maruca spp./ flower and/or pod*	*Clavigralla spp. / plant*	*Thrips / flower*	*Maruca spp./ flower and/or pod*	*Clavigralla spp. / plant*
CNC + XLP	1.83 ^{b}	0.92 ^{b}	2.42 ^{ab}	2.0 ^{b}	0.92 ^{b}	2.0 ^{ab}
CNC + BLP	2.25 ^{b}	0.50 ^{b}	1.50 ^{b}	2.17 ^{b}	0.50 ^{b}	1.67 ^{b}
CNC + GLB	0.83 ^{bc}	0.68 ^{b}	0.92 ^{b}	0.83 ^{bc}	0.67 ^{b}	1.17 ^{b}
CPP + GLB	0.84 ^{bc}	1.92 ^{b}	1.16 ^{b}	0.83 ^{bc}	1.17 ^{b}	1.33 ^{b}
XLP + BTL	2.0 ^{b}	1.25 ^{b}	2.17 ^{ab}	2.17 ^{b}	1.34 ^{b}	2.33 ^{ab}
Uppercott	0.17 ^{c}	0.17 ^{b}	0.25 ^{b}	0.25 ^{c}	0.25 ^{b}	0.42 ^{b}
Control (0.0)	3.83 ^{a}	3.83 ^{a}	4.59 ^{a}	4.84 ^{a}	4.42 ^{a}	5.84 ^{a}
S. E. $\pm$	0.51	0.83	0.79	0.47	0.75	0.74

Means followed by the same character(s) in a column are not significantly different by SAS-SNK test at ($P < 0.05$).
Keys: *CNC* – Cashew nutshell, *XLP* – African pepper, *BLP* – West African black pepper, *CPP* – Chilli pepper, *GLB* – Garlic bulb, *BTL* – Bitter leaf (*Vernonia* sp.)

Generally, higher pod density was obtained per plant in all the treated plots compared with the untreated plots (Table2). Uppercott treatment recorded the highest ($P < 0.05$) pod density per plant compared with plant extracts mixture treatments. Chilli pepper + garlic bulb and cashew nutshell + garlic bulb extract mixtures gave higher pod density than the other two plant extract mixtures. The extent of damage caused by hemipterous insects on cowpea pods sprayed with different mixtures of plant extracts is presented in Table 2. The highest reductions of pod damage among plant extracts

were observed on plots treated with cashew nutshell + West African black pepper which were significantly ($P < 0.05$) lower than in the other extract mixtures sprayed plots. Next to this was cashew nutshell + garlic bulb treated plots. Uppercott sprayed plots recorded the least pod damage of all the treated plots while the untreated control had the highest ($P < 0.05$) pod damage in the two seasons. Grain yields were substantially increased ($P < 0.05$) over the untreated control check following the application of plant extracts mixtures (Table 2). Yields obtained from plots sprayed with cashew nutshell + West African black pepper, cashew nutshell + garlic bulb were superior ($P < 0.05$) to those of chilli pepper + garlic bulb, African pepper + bitter leaf while cashew nutshell + garlic bulb mixture was not superior to cashew nutshell + African pepper. However, Uppercott sprayed plots recorded the highest ($P < 0.05$) grain yield compared to the other plant extracts mixture treatments in the two seasons.

Table 2: Effects of botanical mixtures on mean pod density, pod damage (%) and grain yield of cowpea.

Treatment	*2000*			*2001*		
	Pod density per plant	*Pods infested per plant (%)*	*Grain yield (kg/ha)*	*Pod density per plant*	*Pods infested per plant (%)*	*Grain yield (kg/ha)*
CNC + XLP	32.94 ^{b}	20.78 cd	640.26 d	32.28 ^{b}	20.57 ^{cd}	633.86 ^{d}
CNC + BLP	30.39 ^{b}	15.07 ^{e}	723.33 ^{e}	29.78 ^{b}	14.92 ^{e}	716.10 ^{e}
CNC + GLB	41.33 ^{c}	18.62 ^{d}	690.66 ^{de}	40.50 ^{c}	18.43 ^{d}	683.75 ^{de}
CPP + GLB	42.28 ^{c}	22.69 ^{c}	587.98 ^{c}	41.43 ^{c}	22.46 ^{c}	582.10 ^{c}
XLP + BTL	32.89 ^{b}	25.71 ^{b}	480.67 ^{b}	33.23 ^{b}	25.45 ^{b}	475.86 ^{b}
Uppercott	49.83 ^{d}	11.36 ^{f}	1273.33 ^{f}	48.83 ^{d}	11.25 ^{f}	1201.20 ^{f}
Control (0.0)	8.62 ^{a}	89.29 ^{a}	193.78 ^{a}	8.45 ^{a}	88.40 ^{a}	192.04 ^{a}
S. E. $\pm$	1.61	0.98	17.64	1.33	0.69	12.67

Means followed by the same character(s) in a column are not significantly different by SAS-SNK test at ($P < 0.05$).
Keys: *CNC* – Cashew nutshell, *XLP* – African pepper, *BLP* – West African black pepper, *CPP* – Chilli pepper, *GLB* – Garlic bulb, *BTL* – Bitter leaf (*Vernonia* sp.)

4 Discussion

Different formulations of plant extracts mixtures caused various degrees of reductions of the target pests and also offered various levels of protection to the flowers and pods against damage by thrips, pod borer larvae and pod sucking bugs. Although, the mixtures of cashew nutshell + garlic bulb, chilli pepper + garlic bulb controlled thrips and pod sucking bugs better than cashew nutshell + West African black pepper, they were inferior to the latter on pod borers control. Thus, while there were higher pod densities in the former, the latter (cashew nutshell + West African black pepper) caused drastic reduction of pod damage and higher grain yield on treated plots. This study ranked cashew nutshell + West African black pepper, cashew nutshell + garlic bulb, and cashew nutshell + African pepper (in that order) superior to chilli pepper + garlic bulb, African pepper + bitter leaf extract mixtures in grain yields.

These findings confirmed earlier work done by some researchers (Allen *et al.*, 1944; Snoek, 1984; Jung, 1938), which indicated that combining two or more plant materials in botanical formulations is more potent than when only one plant material is used. However, the performance of chilli pepper + garlic bulb mixture in this study was contrary to the findings of Yepsen (1976) who reported that mixing two finely grated garlic bulbs and two teaspoon chilli peppers into four liters of hot water in which a small nut sized piece of soap was dissolved was effective against caterpillars infesting fruit trees. In Nigeria, some of the plant materials used in this study have been found individually effective in storage pest's control (Oparaeke, 1997; Oparaeke and Bunmi, 2004; Oparaeke and Daria, 2004; Olaifa and Erhun, 1988; Ivbijaro, 1990; Okonkwo and Okoye, 1996). Information on the use of plant extracts for field pests control is limited. However, Oparaeke (2004), Olaifa *et al.* (1987) and Amatobi (2000) have shown that these plant extracts exhibited varying degrees of efficacy on pests of field cowpea. This is the first time a mixture of plant extracts are employed to effectively checkmate the nuisance of pests on cowpea plants in Nigeria.

The results of the present study indicate that extract mixtures of cashew nutshell, garlic bulbs and West African black pepper can significantly reduce thrips, pod borers and pod sucking bugs on cowpea plants. Although, during the investigations the untreated control harboured more pod sucking bugs, there were no statistical difference between it and the treated plots. This could be attributed to the high mobility of the coreid bugs and the weeklong interval between treatment applications, which might have allowed reinfestation of the treated plots. Another reason might be that the bugs prefer to feed on cowpea pods and are easily attracted to pods whether sprayed or unsprayed, though without causing much damage to the latter as observed in this study. The major active principles contained in the plant materials include, West African black pepper - piperine and chavicine, phenylpropanoid, myristicine (sarisan, safrole and elemeicin) and 5 1-mono-sesquiterpenoids (Oliver, 1959; Su, 1977); garlic bulb - mainly sulphur compounds such as Allicin, Di-allyl-disulphide, Allim (Khritchevsky, 1991), thioacrolein, ajoene, 2-propene sulfenic acid, 2-propene thiol and propylene (Jain and Apitz-Castro, 1993). African pepper contains annonaceine (Watt and Breyer-Brandwijk, 1962; Kerharo and Adams, 1974), which may have repellent activity (Burkill, 1985). Cashew on the other hand contains cardole (which is caustic and vesicant on skin) and anacardic acid (Burkill, 1985). These active principles contained in the respective materials when in combination with each other may act synergistically to enhance the toxic substances in the extract mixtures either by increasing or prolonging their effects.

5 Conclusion

The results of this investigation shows that botanical mixtures could form the basis for a successful formulation and commercialization of Biopesticides in developing countries, where low input agriculture is in vogue. In Nigeria, these plants are readily available in the local markets all the year round for farmers' use to protect their crops. Since the materials are used in ethno-botany for the treatment of various ailments, they are safe,

cheap, easily biodegradable, and technologically and environmentally friendly. They could provide valuable alternatives to the synthetic insecticides in the management of post flowering insect pests of cowpea in limited resource farmers farms. Further studies are required to ascertain their optimum mixture levels and spraying schedules for optimum grain yield.

Acknowledgement
The authors are grateful to Mr Gideon Gbilin for his technical assistance and to the Director of the Institute for Agricultural Research, Ahmadu Bello University, Zaria for his kind permission to publish this report.

References

Allen, T. C., Dicke, R. J. and Harris, H. H.; *Sabadilla*, *Schoenocaulon* spp. with reference to its toxicity to houseflies; *Journal of Economic Entomology*; 37(3):400 – 407; 1944.

Amatobi, C. I.; Cashew plant crude extract as a promising aphicide in cowpea insect pest management; Abstracts of paper and poster presentations, World Cowpea Research Conference 111, 4 - 7 September 2000, Ibadan, Nigeria. p. 11.; 2000.

Anonymous; Peasants against "modern" technology; Asian Action 11: 4 (Thailand); 1977.

Burkill, H. M.; *The useful plants of West Tropical Africa (2nd Ed.), Vol. 1: Families A - D.*; Royal Botanic Gardens, Kew; 1985; 960 pp.

Ivbijaro, M. F.; The efficacy of seed oils of *Azadirachta indica* A. Juss and *Piper guineense* Schum and Thonn on the control of *Callosobruchus maculatus* Fab.; *Insect Science and its Application*; 68:339 – 343; 1990.

Jacobson, M.; *Insecticides from plants: a review of the literature, 1941 - 1953*; U.S Dept. Agric. Handbook, 154. U.S Department of Agriculture, Washington; 1958; 299 pp.

Jacobson, M.; *Insecticides from plants: a review of the literature, 1954 - 1961*; U.S Dept. Agric. Handbook, 461. U.S Department of Agriculture, Washington; 1975; 138 pp.

Jain, M. K. and Apitz-Castro, R.; Garlic: a product of spilled ambrosia; *Current Science*; 65:148 – 156; 1993.

Jung, K.; Pflanzliche insektizide (*Pyrethrum*, *Derris*, *Mundulea*, *Lonchocarpus*, *Tephrosia* u.a.); *Tropenpflanzer*; 41:431 – 443; 1938.

Kerharo, J. and Adams, J. G.; Premier inventaire des plantes madicinales et toxiques de la Casamance, Senegal; *Annals of Pharm. Franc.*; 20:726 – 744, 823 – 841; 1974.

Khritchevsky, D.; The effect of dietary garlic on the development of cardio - vascular disease; *Trend in Food Science and Technology*; 2(6):141 – 143; 1991.

Okonkwo, E. U. and Okoye, W. I.; The efficacy of four seed powders and the essential oils as protectants of cowpea and maize grains against infestation by *Callosobruchus maculatus* (Fab.) (Coleoptera: Bruchidae) and *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae) in Nigeria; *International Journal of Pest Management*; 42(3):143 – 146; 1996.

Olaifa, J. I. and Erhun, W. O.; Laboratory evaluation of *Piper guineense* for the protection of cowpea against *Callosobruchus maculatus* Fab.; *Insect Science and its Application*; 9:55–59; 1988.

Olaifa, J. I., Erhun, W. O. and Akingbohungbe, A. E.; Insecticidal activity of some Nigerian plants; *Insect Science and its Application*; 8(2):221 – 224; 1987.

Oliver, B.; Nigeria's useful plants. Part 11. Medicinal Plants (4); *Nigerian Field Journal of Nigerian Field Society*; 24(4):160 – 182; 1959.

Oparaeke, A. M.; *Evaluation of comparative efficacy of some plant powders for the control of* Callosobruchus maculatus *(F.) (Coleoptera: Bruchidae) on stored cowpea*; Master's thesis; Ahmadu Bello University; Zaria, Nigeria; 1997; 105 pp.

Oparaeke, A. M.; *Collection, identification and screening of indigenous herbal extracts and waste matter for control of insect pests of cowpea*; Ph.D. thesis; Ahmadu Bello University; Zaria, Nigeria; 2004.

Oparaeke, A. M. and Bunmi, J. O.; Insecticidal potential of cashew, *Anacardium occidentale* L. powder products for control of *Callosobruchus subinnotatus* (Pic.) on *Bambarra groundnut*; *Nigerian Journal of Agric. Extension*; in Press; 2004.

Oparaeke, A. M. and Daria, V.; Toxicity of herbal powders to emphCallosobruchus maculatus (Fab.) on stored cowpea grains; *Nigerian Journal of Entomology*; in Press; 2004.

SAS Institute; *SAS User's Guide. Version 6.06 Edition*; SAS Institute, Cary, N. C.; 1989; 63 pp.

Schmutterer, H.; Ten years of neem research in the Federal Republic of Germany; in: *Natural Pesticides from the neem tree (*Azadirachta indica *A. Juss)*, edited by Schmutterer, H., Ascher, K. R. S. and Rembold, H.; 21–32; Proceedings, First International Neem Conference; Rottach-Egern, Germany; 1981.

Snoek, H.; *Naturgemäße Pflanzenschultzmittel. Anwendung und Selbstherstellung*; Pietsch Verlag, Stuttgart; 1984.

Sommers, P.; *Low cost farming in the Humid Tropics: An illustrated handbook*; Island Publishing House Inc., Manila, Philippines; 1983; 217 pp.

Stoll, G.; *Natural Crop Protection in the Tropics*; AGRECOL,Margraf Publishers; 1988; 188 pp.

Su, C. H. F.; Insecticidal properties of black pepper to rice and cowpea weevils; *Journal of Economic Entomology*; 70:18 – 21; 1977.

Watt, J. M. and Breyer-Brandwijk, M. G.; *The medicinal and poisonous plants of southern and eastern Africa*; E.&S. Livingstone Ltd.; 1962.

Yepsen, R. B.; *Organic Plant Protection*; Rodale Press, USA; 1976.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 106, No. 1, 2005, pages 49–57

Host Preference and Seasonal Variation of Tick (*Amblyomma cohaerens* Donitz, 1909) on Naturally Infested Cattle in Jimma Zone, Southwestern Ethiopia

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Abstract
The seasonal dynamics of tick *Amblyomma cohaerens* on naturally infested cattle in Jimma Zone was studied from September 1998 to September 2000 using fifty cattles in five Localities. Monthly tick counts were made for two consecutive years. Although, *Amblyomma cohaerens* infestation occurred throughout the year, it was greater at the beginning and end of the rainy season. High humidity and temperature were the factors that influence the seasonal variation. The study on the host preference of different blood groups showed that host selection and specificity correlate with the abundance and distribution of the tick. These have been reflected by the presence of more tick in highbred cattle than the indigenous *Zebu*.

Keywords: *Amblyomma cohaerens*, breed preference, cattle tick, Ethiopia, seasonal variation

1 Introduction

The bites of *Amblyomma* ticks are severe. They may result in septic wounds and abscesses, inflammation of the teats of cows and considerable damage to hides and skins. The tick *Amblyomma cohaerens* is the main vector of *Cowdria ruminantum* and *Dermatophilus congolensis* in southwestern parts of Ethiopia. In the western Ethiopia, acute dermatophylosis is the major cause of economic loss resulting from the tick. The epidemiological and ecological aspects of *Amblyomma cohaerens* have received considerable study (Morel, 1980; Lalle, 1981; Castro, 1994; Mekonnen, 1996). Limited field data on its seasonal activity and development are available (Castro, 1994).

Amblyomma cohaerens is the most abundant tick species that is followed by *Boophilus decoloratus* in the southwestern Ethiopia (Pegram *et al.*, 1981; Castro, 1994). It is considered to be one of the principal ectoparasite of cattle in the region. The economic loss resulting directly or indirectly from tick infestation may be considered as an important factor that impedes the development of exotic cattle in these regions.

The *Amblyomma* ticks are ornate, large and broad. They have a long gnathosoma with basis capituli rectangular dorsally. Eyes and festoons are present. Coxae 1 are usually

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with two spurs. Spiracles are triangular. Male is without ventral plates, but small chitinous plaques may be present close to the festoons. Anal groove surrounds the anus posteriorly. They are usually ornate, so the *Amblyomma* ticks are frequently called the bont ticks. Bont is the African word referring to the presence of brightly colored patterns on their backs and their brown and white-banded legs (BARNARD, 1984; SOLOMON and KAAYA, 1998).
Two different types of *A. cohaerens* have been observed in Ethiopia. A larger type believed to be associated to wild hosts, particularly African Buffalo and a smaller one from cattle. My collection showed only the second type. Previous records from the western zone, A. cohaerens have been found between 1200-1800 mm rainfall in both rainfall types. It was collected from areas of broad-leaved forest (PEGRAM *et al.*, 1981).

In the present survey, *Amblyomma cohaerens* was recorded from all altitude zones but it predominated between 1600-2400m. It was recorded between 800 and over 2600 mm rainfall although it was absent from the rainfall zone between 1000-1200 mm, probably due to chance. This observation support previous findings that *A. cohaerens* is the most abundant tick in Jimma zone (ABEBAW, 1996; PEGRAM *et al.*, 1981; CASTRO, 1994).

Seasonality: In those localities with rainfall most of the year, *A. cohaerens* females were mostly collected between January and September before and during the rainfall peak and less collected between October and December after the rainfall peak. Nymphs were mostly collected between January and April just before the rainfall peak and were less common between June and during the rains. Larvae were most between March and April before the rains. In localities with summer rains none of the instars showed a trend in regard to abundance of collections (PUNYUA *et al.*, 1991; CASTRO, 1994).

2 Materials and Methods

The study was carried out in five localities of Jimma zone (Jiren, Bore, Blida, Merewa and Jimma University, College of Agriculture dairy farm). These areas were selected on the basis of location, altitude and cattle population. The collection have been done from fifty cattle thirty five indigenous zebu and fifteen Zebu crosses with Friesian having different blood level from ten to thirty six months of age representing different management systems, sex and weight groups. These cattle have been selected from herds of the study area based on an initial tick count. Ten cattle from each locality with high infestation in the initial tick count were selected and ear tagged.

The selected cattle were hand sprayed with *Norotraz* 12.5% (from Norbrook Laboratory Limited, Newry, North Ireland) to standardize tick burdens at the beginning and then left in their respective herd for a month until sampling commences. Monthly whole bodies collections of tick have been accompanied by general check up of health status. There was no acaricide treatment during the whole study period. The collection was done on the selected cattle from September 1998 to August 2000. In the course of the two years seven cattle have been replaced because five died and two were sold.
Every 27-30 days the animals were put in crash or restrained to allow whole body collection of ticks according to the method of LONDT *et al.* (1979). Collected samples have been placed in sample vials containing 6% formalin with glycerin. The samples

were labeled immediately after the collection from each animal body was finished. The label contains the locality, animal identification number, date and month of collection. The samples then were counted and identified in the laboratory using hand lens and stereomicroscope on the same day or on the next day. Identification was done based on morphological and structural differences of the species and different instars. The grouping to their genus and species was made according to the methods developed by HOOGSTRAAL (1956) and KEIRANS and ROBBINS (1999). Other species of ticks were discarded after the identification. Along these, ecology, metrological data and environment of the region were taken in to consideration.

The association of the tick count with the metrological data and the trend of development have been statistically analyzed. The statistical analysis was done using correlation between the tick count, temperature and relative humidity and also the association between the larval, nymph + adult stage of the tick. The monthly variations of tick count by instars have been analyzed by analyses of variance (ANOVA). The relationships between the minimum temperature, relative humidity and maximum temperature with the number of ticks and their instars have been analyzed by correlation of variables. The dependent variables of interest were Larvae, Adult +Nymph and total Boophilus decoloratus population (count). Data were analyzed using the General Linear Model (GLM) procedures of SAS (1996) by fitting a fixed effect model with the effects of Year, Site (Locality) and Month. The Tukey's studentized range test was used to separate means with significant variation. Correlations between the dependent variables and relative humidity, minimum and maximum temperature were computed using PROC CORR of SAS (SAS, 1996). Least squares means obtained from the analyses of the model described were used to prepare graphs to illustrate the relationships between the dependent variables (Larvae, Adult + Nymph and total populations) with month.

3 Results

Results of overall means, least squares means (and S.e.), Cv. (%) and F-test of effects of year and site for larva, adult + nymph and total *Amblyomma cohaerens* are summarized in table 1. There were no significant differences in the infestation (total tick count) between the years. However, significant differences were observed in total tick count between months and the sites. There was considerable variation between JCA farm tick count and other localities. This suggests that JCA farm cattle were more susceptible to tick infestation than the others. This difference observed was based on the breed difference, while cattle of JCA farm was a mainly exotic breed. In the study conducted in a different location on different tick species, cattle with exotic blood had higher mean infestation rate than the local *Zebu* cattle. Thus, local cattle resist tick infestation better than the exotic one.

The result on the effect of environment on tick population indicate that *Amblyomma cohaerens* is highly dependent on moist microenvironments because of its great susceptibility to percentage losses of total body water, and drop in hemolymph volume at low humidity. This study illustrates that *Amblyomma cohaerens* perish rapidly when the humid protection is disrupted. Seasonal activity began in March when larvae exhibited

Table 1: Overall means, Least squares means, Cv. (%) and F-test of effects of year and site for larva, adult+nymph and total *Amblyomma cohaerens*

Effect and level	*Larva*	*Adult + Nymph*	*Total*
Overall	38.5	41.2	79.7
C.V.	26.8	29.3	24.2
Year	Ns	Ns	Ns
1998/99	37.3	42.5	79.8
1999/2000	39.7	39.9	79.6
Site	**	**	**
Blida	28.0 ^{b}	31.5 ^{b}	59.6 ^{b}
Bore	33.8 ^{b}	35.8 ^{b}	69.5 ^{b}
JCA	69.8 ^{a}	74.5 ^{a}	144.3 ^{a}
Jiren	28.3 ^{b}	27.6 ^{b}	55.9 ^{b}
Merewa	32.5 ^{b}	36.5 ^{b}	69.0 ^{b}

** $\hat{=}$ sigificant at $P \leq 0.01$; NS $\hat{=}$ not significant

host-seeking behavior on the ground. Ticks began to come up to the top of vegetations in April and early May, and a peak in the percentage of ascending tick reached in late May, June and beginning of July. The percentage ascending remained constant until mid July when ticks began to go down to the root of vegetations in association with higher humidity and lower temperature. Thus climatic factors seemed to greatly influence cattle tick infestation.

Amblyomma cohaerens had two peaks of activity, in September and October (moderate) and in May, June and July (maximum). No significant increase in tick population was observed during the short rains. There was, however, a greater buildup coincidence with the main rainy season. There was a direct relationship between population and minimum temperatures, whereas maximum temperature seemed to have no such relationship. The Patterns of seasonal activity for *Amblyomma cohaerens* on cattle in Jimma zone is shown in (Fig.1)

There were substantial variations in the total tick count and developmental stages between months as indicated the Table 2.

Table 3 shows the correlation coefficient between larva, adult+nymph and total *Amblyomma cohaerens* and minimum temperature, maximum temperature and relative humidity. All correlations are significantly different from zero ($P < 0.01$). Tick count and maximum temperature were negatively correlated. Tick count was positively correlated with minimum temperature and relative humidity.

Figure 1: Seasonal variation of the population of total, adult and larvae of *Amblyomma cohaerens*.

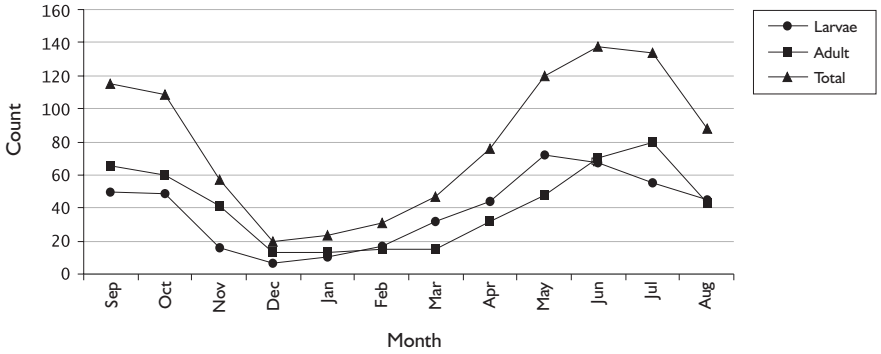

Table 2: Least squares means for larva, adult+nymph and total *Amblyomma cohaerens* in different months for the years 1998/99 and 1999/2000

Month	*Larva*	*Adult + Nymph*	*Total*
September	49.6	65.2	114.8
October	48.5	59.6	108.1
November	15.6	41.2	56.8
December	6.6	13.5	20.1
January	10	13.4	23.4
February	16.4	14.7	31.1
March	31.5	14.9	46.4
April	44.1	31.7	75.8
May	72.3	47.3	119.6
June	67.2	70.6	137.8
July	54.8	79.2	134
August	45	43	88

The growth and multiplication of all instars of *Amblyomma cohaerens* were correlated with mean air temperature. The habitat most favorable for it was also most moderate in terms of temperature and relative humidity. Consequently, the environmental conditions created within a vegetation, specifically temperature and relative humidity, are more important for the survival of *Amblyomma cohaerens* than plant species comprising that area.

Thus, when temperature is low and relatively humidity high in May, June and July, the population of *Amblyomma cohaerens* ascends vegetation and awaits a host. When temperature is high and relative humidity low from November to March, ticks descend the vegetation and seek shelter in the soil and leaf litter. *Amblyomma cohaerens* seek

Table 3: Correlation coefficient between larva, adult + nymph and total *Amblyomma cohaerens* and minimum temperature, maximum temperature and relative humidity.

	Min. Temp.	*Max. Temp.*	*R. Humidity*
Larva	0.47 (**)	- 0.46 (**)	0.48 (**)
Adult+Nymph	0.44 (**)	- 0.51 (**)	0.50 (**)
Total	0.47 (**)	- 0.51 (**)	0.51 (**)

All correlations are significantly different from zero at $P \leq 0.01$

hosts by moving across the ground in March and April and by ascending vegetation in May, June and July. The earliest significant activity of *Amblyomma cohaerens* begins in May when the average ambient temperatures are 19-21 °C. Of course, soil surface temperatures may rise significantly above this. Peak populations occur in May, June to mid July, from mid July to August short decline and another peak in September then further decline until almost non-observed in late December and January. This phenomenon was also observed during other years.

Temperature and humidity measurement in the zone indicated very high day temperatures and low humidity and considerable cooling and a raise in relative humidity during the night. High summer temperatures influence the behavior of ticks in all habitat types. This condition probably results in shorter longevity in certain habitats. As a behavioral response to rising temperatures during November to April, ticks migrate down the vegetation to the soil.

Rainfall and the directly related relative humidity are the main climatic factors influencing tick distribution and activity. A peak of activity for most species was detected at the beginning of the heavy rain (June-July). Due to the extreme difference in rainfall and relative humidity during the year tick numbers during the dry season are low with a marked increase coinciding with the start of the rains. Relatively high tick burdens last throughout the rainy season.

The result from the analysis of variance for larva, adult+nymph and total *Amblyomma cohaerens* in table 4 indicate that site and month had a significant ($P < 0.01$) effect on infestation.

4 Discussion

The ticks were found on the cattle during every month of the year, but there was a reduction in the number of ticks per animal during the dry season. Rainfall was the climatic factor that most affected the seasonal variation in the tick infestations (Pegram *et al.*, 1984). The present result was consistent with those of (Asres and Gebre-Ab, 1991) who studied the tick fauna and seasonal dynamics at Abernosa ranch they found out that minimum temperature had higher effect than maximum temperature.

Table 4: Analysis of variance for larva, adult and total *Amblyomma cohaerens*.

Source	*Larva*		*Adult+Nymph*		*Total*	
	DF	*F-value*	*DF*	*F-value*	*DF*	*F-value*
Year	1	1.67 ^{NS}	1	1.41 ^{NS}	1	0.00 ^{NS}
Site	4	70.58 **	4	59.15 **	4	86.17 **
Month	11	46.29 **	11	39.28 **	11	50.60 **

** $\hat{=}$ $P < 0.01$; NS $\hat{=}$ Not significant

Although ticks were present on the animals during each month of the experimental period, two peaks of infestation could be distinguished between September 1998 and August 2000, each of which probably corresponded to a new generation of ticks. These data are in agreement with the observations of SOLOMON and KAAYA (1998) who studied the development reproductive capacity and survival of *Amblyomma variegatum* and *Boophilus decoloratus* in relation to climatic factor and host resistance under field condition and noted the occurrence of two generations of the tick per year.

The degree of infestation of the animals with larvae is related to the influence of climatic factors on the production and survival of the non-parasitic stages. Hence the seasonal variation of ticks on the animals presented a direct association with the availability of larvae in the pastures, i.e. during the months of low infestation the population of larvae available in the pastures is relatively low (SUTHERST, 1989). Rainfall appeared to be the climatic factor that most influenced the seasonal variation in the intensity of infestations of *Amblyomma cohaerens* in the study area during the experimental period.

Peaks in the number of ticks were preceded by rainfall, as observed by WILKINSON (1982). In South Africa, ROBERTSON (1981) found out that a monthly rainfall of 100 mm/month or lower created unfavorable conditions, resulting in a gradual fall in the numbers of available larvae. In the present study, it was found out that only monthly rainfall in excess of 250 mm produced a reduction in *Amblyomma cohaerens* infestations.

An increase was observed in the number of ticks in May to July 1999 and 2000, immediately following the beginning of the rainy season. During the dry season (November to April), when rainfall and humidity were lower, there was a sharp reduction in *Amblyomma cohaerens* infestations, producing the lowest counts in the observation period. A small peak occurred in September to October 1998 and 1999 that can probably be related to the increase of temperature and reduction of rainfall that occurred in these months. These data confirm the observation of GRAY and POTGIETER (1982). The onset of the rainy season (May-June) produced a rise in infestation levels, which then remained relatively high until July, when there was a reduction that was probably due to excessive rain. No correlations were observed between maximum temperature and the seasonal variation of *Amblyomma cohaerens*.

The fluctuations in infestation levels showed the same pattern during both years of the study although the peaks were of different intensities. Lower infestations were observed during the second year of the study, when the animals were getting older and developed acquired resistance. Abebaw (1996) observed that heifers and young bulls of highbred cattle presented higher burdens of *Amblyomma cohaerens* than did adults and calves, although Teel *et al.* (1988) did not find any age-related effect on resistance to the tick.

In the present study, both the climatic differences between the two years and the cattle-raising techniques used by the farmers where the study was carried out could have contributed to the lower infestations seen in the adult animals. The calves up to six months of age were maintained apart from adult animals at low population densities and were thus exposed to lower parasite burdens on the pasture.

During the study period, it was observed that fifteen of the animals (30%) maintained 50% of the total parasite load of the group that are mainly exotic breeds, which agrees with the findings of Castro (1994). Identification of the most susceptible animals within a group is an important prerequisite for the adoption of measures to reduce parasitic burden (Claxton and Leperre, 1991). These may involve removing susceptible animals from the herd or using them to remove larvae from the pastures and submitting them to more frequent acaricidal dips (Sutherst, 1989).

Acknowledgment
My great thanks goes to Prof. Dr. Helge Boehnel at Georg-August University Goettingen Germany for his support and advise. I thank Jimma University, College of Agriculture (JUCA) for financial and technical support during the whole experimental period. I appreciate Mr. Abebe Mekonnen and Dr. Ibrahim Hussien at Acarology and Entomology Department of Sebeta Veterinary Research Center, Ethiopia for their help in tick identification and material support.

References

Abebaw, G. K.; *Study on the epizootology of tick and tick borne disease of naturally infested cattle in Jimma zone*; Master's thesis; Univ. of Goettingen; Germany; 1996.

Asres, S. and Gebre-Ab, F.; Survey of the tick fauna and its seasonal dynamic at Abernossa; Institute of Agriculture Research, Addis Ababa (Ethiopia) IAR/NLIC proceedings 3; 1991; pages 168-170.

Barnard, D. R.; Aspects of the bovine host lone star tick; in: *Acarology VI, vol. 1*, edited by Griffiths, D. A. and Bowman, C. E.; 428–443; Ellis Horwood, Chichester; 1984.

Castro, J. J.; *A survey of the tick species in western Ethiopia including previous finding and recommendations for further tick surveys in Ethiopia*; UNDP, Addis Ababa, Ethiopia, FAO, Rome (Italy); 1994.

Claxton, J. and Leperre, P.; Parasite burdens and host susceptibility of Zebu and N'Dama cattle in village herds in Gambia; *Vet. Parasitol.*; 40:293–304; 1991.

Gray, J. S. and Potgieter, F. T.; Studies on the infectivity of *Boophilus decoloratus* male and larva infected with *Babesia bigemina*; *Onderstepoort Journal of Veterinary Research*; 49:1–2; 1982.

Hoogstraal, H.; *African Ixodoidea Vol. 1, Ticks of Sudan*; Department of the Navy, Washington D.C; 1956.

Keirans, J. E. and Robbins, R. G.; A world checklist of genera, subgenera and species of ticks (Acari: Ixodida); *J. Vector Ecol.*; 24:115–129; 1999.

Lalle, K. H.; UNDP Terminal Report (1975-1981) Ethiopia; Ethiopia, pages 55-65; 1981.

Londt, J. G., Horak, I. G. and de Villiers, I. L.; Parasites of domestic and wild animals in South Africa. XIII. The seasonal incidence of adult ticks (Acarina: Ixodidae) on cattle in Northern Transvaal; *Onderstepoort Journal of Veterinary Research*; 46(1):31–39; 1979.

Mekonnen, S.; Epidemiology of ticks and tick-borne diseases in Ethiopia: Proceeding of future research needs and priorities; ILRI, Nairobi (Kenya), pages 17-29; 1996.

Morel, P. C.; Study on Ethiopian ticks (Acarida, Ixodida); French Veterinary Mission, Addis Ababa (Ethiopia); 1980.

Pegram, R., Hoogstraal, H. and Wassef, H. Y.; Ticks (Acari: Ixodoidea) of Ethiopia, I. Distribution, ecology and host relationships of species infesting livestock; *Bulletin of Entomological Research*; 71:339–359; 1981.

Pegram, R. G., Perry, B. D. and Schels, H. F.; Seasonal dynamics of the parasitic and non-parasitic stages of cattle tick in Zambia; in: *Acarology VI, Vol. 2, Seasonal dynamics of the parasitic and non-parasitic stages of cattle tick in Zambia*, edited by Griffiths, D. A. and Bowman, C. E.; 1183–1187; Ellis Horwood, Chichester; 1984.

Punyua, D. K., Latif, A. A., Nokoe, S. and Capstick, P. B.; Tick (Acarei: Ixodidae) infestations on Zebu cattle in Western Kenya: seasonal dynamics of four species of tick on traditionally managed cattle; *Journal of Medical Entomology*; 28(5):630–636; 1991.

Robertson, W. D.; A four-year study of the seasonal fluctuations in the occurrence of the blue tick *Boophilus decoloratus* (Koch) in the coastal regions of the eastern Cape, South Africa; Tick Research Unit; 1981; 199pp.

SAS; *Statistical Analysis System for Mixed Models*; SAS Institute Inc., Cary, NC, USA; 1996.

Solomon, G. and Kaaya, G. P.; Development, reproductive capacity and survival of *Amblyomma variegatum* and *Boophilus decoloratus* in relation to host resistance and climatic factors under field conditions; *Vet. Parasitol.*; 75:241–253; 1998.

Sutherst, R. W.; Resistance of cattle to ticks and one element in a control Program in Mexico; FAO Animal production and health Paper, pages 154-164; 1989.

Teel, P. D., Bay, D. E. and Ajidafba, P. A.; Ecology, distribution and host relationships of ticks infesting livestock in Mali; *Bulletin of Ento. Research*; 78:407–424; 1988.

Wilkinson, P.; Ecological aspect of pest management of Ixodid ticks; in: *Acarology IV, Vol. 2*, edited by Griffiths, D. A. and Bowman, C. E.; 25–33; Ellis Horwood, Chichester; 1982.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 106, No. 1, 2005, pages 59–70

Technical Efficiency of Resource Use in the Production of Irrigated Potato: A Study of Farmers Using Modern and Traditional Irrigation Schemes in Awi Zone, Ethiopia

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Abstract

Based on cross-sectional data collected from randomly selected 80 farmers in four districts of Awi zone in North-western Ethiopia, this study examines the technical efficiency of farmers in the production of irrigated potato. The stochastic frontier production function, which considers deviation from the frontier to be due to the effect of technical inefficiency and random noise, is used for data analysis. Technical efficiency of farmers was estimated independently for the farms under modern irrigation schemes and traditional irrigation schemes. Using likelihood ratio test, Translog production function is found to be an adequate representation of the production behavior of farms under the two types of schemes.

The mean level of technical efficiency was found to be 77 percent and 97 percent respectively for modern and traditional schemes. Therefore, improving the level of efficiency could raise productivity under modern schemes, whereas improving productivity under traditional schemes needs introduction of new technology as the farmers' level of production has approached the frontier. Irrigation experience, commodity rate of production and size of livestock are found to be the important variables that determine the level of efficiency.

Keywords: technical efficiency, stochastic frontier, irrigated potato

1 Introduction

At current per capita fresh water resource of 1924 cubic meters, Ethiopia is one of the countries endowed with the largest fresh surface water resources in Sub-Saharan Africa. More over, Ethiopia's land resource potential for irrigation development, disregarding available water is very large. Despite this potential, Food and Agricultural Organization estimates showed that 49% of Ethiopia's population is undernourished (FAO, 2001). At the root of this problem is the low agricultural productivity. Cereal yields stagnated at around 1.2 tones per hectare between 1980 and 2002. Moreover, the country's agriculture is dependent on unreliable rainfall. Agricultural production may fall by up

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to 20% in years of drought. Untimely and/or excessive rainfall in many areas can also affect grain production negatively.

With little room for further significant increase in the area under cultivation, the solution to the country's food supply problem hinges on raising yields through sustainable growth in the use of external inputs, particularly fertilizer and improved seeds besides the development of irrigation. Since 1992, the government has taken several measures aimed at improving smallholders' productivity such as removing government monopolies and restrictions on private trading, encouraging private sector participation in the agricultural input market, and provision of logistic and technical support for the development of irrigation services.

Three major types of irrigation schemes are practiced in Ethiopia: traditional schemes, modern community schemes and large-scale schemes. Large-scale irrigation is mainly concentrated in Awash Valley and operated by state farms. Traditional irrigation schemes are small-scale irrigation schemes built under the self-help program of peasant farmers on their own initiative. The schemes are operated and maintained by farmers themselves. Traditional water use associations led by elected chiefs, undertake the operation and maintenance of traditional irrigation schemes. Modern community irrigation schemes are largely constructed by the government and/or Non-governmental Organization (NGO) with the participation of farmers. In Awi Zone, five modern community irrigation schemes have been constructed, irrigating a total area of 1,097.4 hectares (ANRSBPED, 2001). Annual crops account for about 87% of irrigated crops in the study area, the dominant irrigated crops (in year 2002) being potato, barley, wheat and shallot in order of their area coverage.

In countries like Ethiopia, where food deficit is prevalent due to recurrent droughts, the challenges of moisture stress could be met with irrigation schemes that make the best of the available irrigation technology. One of the necessary agenda in this context would be a study on resource use efficiency and the factors that contribute to resource use efficiency in the production of irrigated crops. Therefore, this study investigates the level of technical efficiency of irrigated potato farms and identifies the factors that limit the level of efficiency for the schemes under consideration.

2 Objectives of the Study

In general, the objective of this study is to examine as to how to use resources efficiently in order to increase the level of output obtained from irrigated farms in Awi zone, given the available resources and the existing state of the art. It focuses on the assessment of resource use efficiency in the production of irrigated potato under traditional irrigation schemes and modern community irrigation schemes. The specific objectives of the study are:

(a) To evaluate technical efficiency of irrigated potato farms under the traditional irrigation schemes and modern communal schemes, and

(b) To identify the determinants of technical efficiency in irrigated potato production, so as to assist in finding ways and means by which the level of technical efficiency could be increased.

3 The study set-up and Methodology

3.1 Sample Data and Variables

A combination of purposive and random sampling techniques was employed to draw a sample of 40 farmers for the study under each category of schemes. A cross-sectional data for the year 2002/2003-irrigation crop season were collected. The methods used were interviewing and recording through frequent follow-up of the farmer in the production process. Relevant data were collected from both secondary and primary sources.

In the production function analysis, the independent variables are predetermined in the sense that they are the actual inputs for production and the dependent variable is the output. Thus, what may be required here is to make clear how these input variables and output are measured and used in the analysis. Six input variables (area, draught power, labor, operating expenses, asset expenses, and number of days of irrigation) were selected, as they are major ones necessary for irrigated potato production.

3.2 The Stochastic Frontier Model

The stochastic production frontier production functions were used to analyze the data for the two groups of farmers. AIGNER *et al.* (1977) proposed stochastic models assuming that the disturbance term has two components, that is, $\varepsilon_i = v_i + u_i$. The error component v_i represents the symmetrical disturbance that captures random errors caused outside the firms' control such as measurement errors, random shock, and statistical noise. This component is assumed to be identically and independently distributed as $v_i \sim N(0, \sigma^2)$. The u_i component of the error term is the asymmetrical term that captures the technical inefficiency of the observations and assumed to be independent of v_i, and also to satisfy that $u_i \geq 0$. The non-negative component (u_i) reflects that the output of each firm must be located on or below its frontier (BATTESE and BROCA, 1997).

The stochastic frontier model is widely applied in the efficiency analysis. For example, GIMBOL *et al.* (1995), ABRAR SULEIMAN (1995), GETU HAILU *et al.* (1998) and XU and JEFFERY (1998), among others, used stochastic frontier models to estimate technical efficiency of farms. The stochastic frontier model, which was found to be an adequate representation of the data in preliminary analysis, is given by:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{6} \beta_{jk} \ln X_{ij} + \sum_{j \leq k=1}^{6} \beta_{jk} \ln X_{ij} \ln X_{ik} + (v_i - u_i) \qquad (1)$$

Where the subscript, i indicates the i-th farmer in the sample ($i = 1, 2, ..., 40$ for each scheme), Y represents physical yield of potato (dt/ha); X_1 represents size of farm land under irrigated potato (ha); X_2 is draught power (oxen-hrs/ha); X_3 is human labour spent in farming the plot (person-hrs/ha); X_4 is operating expenses (Eth. birr/ha);

X_5 represents asset expense (Eth. birr); X_6 is frequency of irrigation (number of times); $\ln$ is natural logarithm (i.e., logarithm to base e); $\ln X_{ij} \ln X_{ik}$ includes the squares and interaction terms of the input variables; β_j's are unknown parameters to be estimated; v_i's are symmetric component of the error term and assumed to be independent and identically distributed having $N(0, \sigma_v^2)$ – distribution; the u_i's are the inefficiency component of the error term, which are assumed to be independently distributed such that u_i is defined by truncation (at zero) of the normal distribution with mean μ_i and variance σ^2 (BATTESE and COELLI, 1995), where μ_i is defined by:

$$\mu_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 \quad (2)$$

where δ's are unknown parameters to be estimated, and $Z_1, Z_2, Z_3, Z_4, Z_5, Z_6, Z_7, Z_8$ and Z_9 represent education level of the household head, credit use, years of experience in irrigation, commodity rate of production, irrigated land size (ha), livestock ownership (TLU), extension contact, farm-home distance and family size, respectively.

Technical efficiency measures are calculated relative to the production function of the fully efficient farm or a unit that is represented by a frontier function. Since in actual practice this frontier value is not known, it must be estimated from a sample of observed yield of each farm, and each farm's performance is compared with the estimated frontier. The purpose of estimating the frontier is to estimate the level of technical efficiency of each observation that is given by exp $(-u_i)$ which lies between zero and one and is inversely related to the level of the technical inefficiency effect. Following COELLI *et al.* (1998), the variance parameters of the stochastic frontier and inefficiency effects, $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2/\sigma^2$, were also obtained using FRONTIER Version 4.1.

4 Results and Discussion

4.1 Level of Technical Efficiency

In this study, individual farm level of efficiency was estimated independently for the farmers operating under modern irrigation schemes and traditional irrigation schemes in the production of irrigated potato. In order to select the appropriate specification of the functional form a likelihood ratio test has been carried out. In this test, the null hypothesis is that the second order and the interaction terms in the Translog functions are not different from Zero (i.e., $H_0 : \beta_{ij} = 0; i \leq j = 1, 2, 3, 4, 5, 6$). The likelihood ratio test rejected the null hypothesis, implying that the Translog form adequately captures the production behavior of irrigated potato farms in Awi Zone, under both types of schemes (Table 1).

The problem of the presence of higher collinearity among the input variables in the Translog function was examined looking the value of Variance Inflation Factor (VIF) of the variables. The results indicated that there is no serious multicollinearity problem.

The computer program FRONTIER version 4.1 gave the values of the parameter estimates for the frontier model, the value of σ^2 and the value of log-likelihood function for both the ordinary least squares estimation and maximum likelihood estimation techniques, in the model output (Table 2). In addition, the maximum likelihood estimation

Table 1: Likelihood ratio test for selecting the functional form.

Efficiency estimation	*Log-likelihood value*		*LR*	$\chi^2_{(21)}$
	Cobb-Douglas (Lc)	*Translog (Lt)*		
Modern schemes	-12.327	10.626	45.906	32.671
Traditional schemes	-22.486	10.532	60.036	32.671

gave the individual and mean level of technical efficiency, the value of the parameter estimates for the inefficiency effects model (i.e., parameter estimates of the explanatory variables for u_i) and the value of gamma (γ).

Making use of the values of the model output the null hypothesis that technical inefficiency effects are not in the model ($H_0 : \gamma = 0$) was tested against the alternative hypothesis that inefficiency effects is in the model ($H_1 : \gamma > 0$). The likelihood ratio test also rejected the null hypothesis ($\gamma = 0$) at 5% level of significance in the case of farms under modern irrigation schemes and accepted it in the case of farms under traditional schemes.

The value of gamma for the frontier of farms under modern irrigation schemes (γ= 0.3689) is also statistically significant at 10% level of significance in terms of t-statistic. Hence there is indeed an inefficiency effect associated with irrigated potato farms under modern irrigation schemes. Therefore, the data for this group of farms can be better represented by the stochastic frontier than the average response function. On the other hand, gamma was not statistically different from zero for those farms operating under traditional irrigation schemes, implying that there is no need to include the inefficiency effect in the model. In other words, the data for the farms under traditional irrigation schemes can be represented by the average response function, which means these farms are technically efficient. Thus, whereas productivity of farms under modern irrigation schemes can be raised through increasing the level of technical efficiency at the existing level of technology and inputs, it needs the introduction of new technologies to increase productivity of farms under the traditional irrigation schemes.

The mean technical efficiency of irrigated potato farms under modern irrigation schemes was found to be 77% with a range of 41 to 98.5%, showing a wider difference in the individual farms' efficiency level. For farms under traditional irrigation schemes, the mean technical efficiency was 97% with a range of 95 to 99.4%. Despite its indication of the general efficiency performance of farms, the mean technical efficiency level may not indicate the actual picture of the distribution of individual efficiency levels. Hence frequency distribution of individual technical efficiency of farms is presented in Table 3.

A statistical test has also confirmed that the mean technical efficiency of the two groups of farms is significantly different at 1% level of significance. Therefore recommendations to be given for the two groups of farms should consider their technical efficiency difference.

Table 2: Maximum-likelihood estimates for the parameters of the Translog stochastic frontier production function for irrigated potato in Awi zone, Ethiopia.

Modern scheme			*Traditional scheme*		
Parameter	*Coefficient*	*t-ratio*	*Parameter*	*Coefficient*	*t-ratio*
β_0	6.439 ***	9.602	β_0	3.720***	3.722
β_1	-355.700***	-373.935	β_1	-205.359***	-206.509
β_2	-181.201***	-190.827	β_2	19.216***	19.342
β_3	-240.955***	-254.443	β_3	-734.626***	-743.139
β_4	891.209***	941.144	β_4	-417.288***	-422.896
β_5	977.626 ***	1031.951	β_5	-94.010***	-94.394
β_6	821.701 ***	-86.702	β_6	-868.590***	-871.135
β_{11}	221.390 ***	288.804	β_{11}	218.221***	223.238
β_{12}	-14.223***	-18.571	β_{12}	42.395***	435.425
β_{13}	712.020 ***	929.007	β_{13}	-218.976***	-229.689
β_{14}	-340.409 ***	-444.809	β_{14}	61.930***	65.476
β_{15}	-15.027***	19.565	β_{15}	51.505 ***	154.029
β_{16}	39.725***	51.752	β_{16}	586.519***	593.487
β_{22}	201.052***	223.622	β_{22}	618.744***	619.659
β_{23}	-97.338***	-107.876	β_{23}	321.673***	322.162
β_{24}	675.089***	751.038	β_{24}	-97.194***	-97.391
β_{25}	-347.710***	-386.105	β_{25}	-695.825***	-696.413
β_{26}	-516.854****	-574.099	β_{26}	-378.471***	-378.662
β_{33}	-80.430 ***	-89.434	β_{33}	431.903***	447.628
β_{34}	-212.558 ***	-236.201	β_{34}	-403.992***	-419.709
β_{35}	-36.311***	-40.377	β_{35}	-791.908***	-808.870
β_{36}	336.968***	374.766	β_{36}	41.557 ***	42.304
β_{44}	81.043 ***	89.788	β_{44}	402.111***	423.285
β_{45}	-378.289***	-418.228	β_{45}	23.968 ***	24.689
β_{46}	-707.755***	-787.205	β_{46}	-7.132 ***	-7.323
β_{55}	-914.857***	-1014.485	β_{55}	803.917***	830.037
β_{56}	161.249 ***	179.249	β_{56}	-411.489***	-423.715
β_{66}	729.226 ***	811.132	β_{66}	450.549***	456.777
σ^2	0.041***	3.248	σ^2	0.0362	0.0684
γ	0.370*	1.898	γ	0.050	0.05003
LL	10.626		LL	10.532	

Note: The β coefficients represent the estimated coefficients for the independent variables defined with Translog function and also square and interaction effects.

Table 3: Frequency distribution of estimated efficiencies.

Estimated efficiencies	*Frequency (%)*	
	Modern schemes	*Traditional schemes*
0.40 - 0.60	15	0
0.61 - 0.70	22.5	0
0.71 - 0.80	20	0
0.81 - 0.90	15	0
0.91 - 0.95	17.5	65
0.96 - 100	10	35

4.2 Determinates of Technical Efficiency

One of the objectives of measuring efficiency is to identify what factors affect its level so as to tackle the problem of low productivity accordingly. Nine socio-economic variables (i.e., education level of the household head, credit, irrigation experience, proportion of the produce marketed, size of the total irrigated land, livestock, frequency of extension supervision, farm-home distance and family size) were used to estimate the model. The coefficients were estimated in combination with the production frontier, the inefficiency component of the error term being considered as the dependent variable, and indicate their effects on inefficiency (Table 4).

Both individual and overall significance tests of the coefficients of the inefficiency variables for the farms under traditional irrigation schemes are not significantly different from zero confirming that there is no inefficiency effect. For farmers under the modern schemes, individual tests for three variables (irrigation experience, livestock and commodity rate of production) were significant. Though individual tests of coefficients of most of the inefficiency variables were not significant, the generalized likelihood ratio test of the overall significance of the coefficients was highly significant indicating the joint effect of these variables on the inefficiency. Therefore, the relationship between the variables (individually or jointly) and technical efficiency of farms needs to be thoroughly discussed.

The effect of education on performance of the agricultural sector in developing countries is sometimes not clear. In this study although it was not statistically significant, the relation between the efficiency level of farmers and education level of the household head was negative, which is different from most of others' empirical findings. Kalirajan and Shand (1988) and Parikh and Shah (1995) for India, Sharif and Dar (1996) for Bangladesh, Xu and Jeffery (1998) for China, Day *et al.* (2000) for Philippines and Mulat Demeke (1989), Abay Asfaw and Assefa Admassie (1996) and Getu Hailu *et al.* (1998) for Ethiopia have found a positive relationship between efficiency and education. Where as Sriboonchitta and Wiboonpongse (2000) found a negative relationship between education and technical efficiency of rice production in

Table 4: The maximum-likelihood estimates for parameters of the inefficiency using Translog stochastic frontier production function for irrigated potato production in Awi Zone.

Variables	*Modern Schemes*		*Traditional Schemes*	
	Coefficient	*t-ratio*	*Coefficient*	*t-ratio*
Constant	-0.280	-0.464	0.0001	0.0001
Education level of the HH head (Z_1)	0.248	1.265	-0.0011	-0.0011
Credit (Z_2)	-0.111	-0.813	0.0034	0.0036
Experience on irrigation (Z_3)	-0.018**	-2.385	-0.0014	-0.0036
Proportion of the produce marketed (Z_4)	0.773**	2.505	0.0011	0.0011
Size of total irrigated land (Z_5)	0.013	0.101	-0.0014	-0.0014
Livestock (Z_6)	0.481*	1.742	0.0048	0.0056
Frequency of extension supervision (Z_7)	-0.083	-0.953	-0.0066	-0.0093
Farm-home distance (Z_8)	-0.024	-1.018	-0.0036	-0.0033
Family size (Z_9)	0.059	1.28	0.0021	0.0023

* , **: differences are significant at 10% and 5% level respectively

Thailand. Where as WHARTON (1965) was unable to establish a meaningful relationship between agricultural production and education level of farmers, and suggested that the contribution of education in the early stages of developing agriculture is uncertain.

In this study we found out that the relationship between irrigation experience and education level of the household head was negative suggesting that those farmers with relatively better years of schooling lack irrigation experience. This is because most of the farmers with relatively higher level of education were having lesser years of irrigation experience. When we look at the coefficient of the variables for the inefficiency effect, irrigation experience has a positive and significant relationship with technical efficiency while the sign of the relationship between education and technical efficiency was negative. From this we can conclude that the art gained through experience had more effect than the effect of education on technical efficiency of irrigated potato farms in Awi Zone. This may be due to the fact that no adequate information (especially in irrigation agronomy) is provided to the farmers so as to benefit educated farmers from it. Further more, the farmer being the planner and decision maker in the production process, long agricultural experience enhances its technical efficiency. The implication here is that farmers can increase their productivity of irrigated crops through acquiring knowledge from those farmers who have the best practice, which they have developed through experience.

Empirical findings also indicate that credit may have different relations with the level of efficiency. In this study, credit has positive relation with the level of technical efficiency though it is not statistically significant. This may be due to the reason that farmers who have got the credit may not use it as intended. In other words, some of them might have used the credit for other purposes.

The results of this study indicated that commodity rate of production has a significant negative effect on the level of technical efficiency, showing the other way the negative impact of self-sufficiency on efficiency. In this analysis, the commodity rate of production is calculated directly by taking the ratio of the produce sold to the total produce. Therefore, the higher the commodity rate of production the less would be the amount of produce left for family consumption. From microeconomics background, this can be explained by the "backward bending" nature of the supply curve for subsistence farmers. For subsistence farmers, the usual price-supply relationship doesn't hold true. The farmer increases supply of the produce until he gets the amount of money desired even if the price decreases, at the expense of his family consumption or he sells only some portion of the produce and consumes the rest of it, if the price is favorable. Therefore, the lesser the price of the produce the higher the ratio of produce sold to the total produce and the lesser would be the amount of produce left for family consumption. Consequently, the proportion of produce sold had a significant negative relation to the level of technical efficiency.

The livestock holding can be a proxy for the wealth position of the farmers, though in some cases, a farmer may have less livestock but can be wealthier at times. Livestock provides draught power, transport service, manure and cash income to finance crop production. Therefore, the relationship between technical efficiency and number of livestock was expected to be positive. The results of this study indicated that livestock negatively affect the level of technical efficiency at 10% level of significance. This may be due to competitive nature of the two enterprises as livestock production competes with crop production for labor and other resources. The other explanation for the negative relationship between livestock and level of efficiency was given based on observation of the real situation during data collection. Most of the sample farms were located around homesteads. The maximum farm-home distance is only a 20 minutes walk, while the average distance takes about 5 minutes walk. Consequently, these farms were exposed to livestock. The proposition was the more the size of livestock a farmer has the more likely would be the extent of crop damage by livestock.

This proposition was verified including farm-home distance in the model. For this analysis, the sign of the coefficient indicated that there is a positive relationship between farm-home distance and technical efficiency. This implies that farms near to homes are less efficient than those located at relatively far distances, supporting on the other way the proposition given for the relationship between livestock and level of efficiency. Whatever the justification may be, the possible policy implication here is that farmers should be advised to have an optimum size of livestock. However, further studies that consider efficiency of all crops under irrigated production would have better implication, as livestock is involved in the production of other irrigated crops too.

Empirical findings of this study have also indicated that extension contact has positive relationship with technical efficiency though it is not statistically significant. This result is not different from the findings of KALIRAJAN and SHAND (1988), which stated that extension contact has no significant relationship to technical efficiency as extension agents do not have new information to provide farmers. Therefore, the policy implication here is to provide regular trainings to extension agents so that they can give new information to the farmers. Moreover, extension services rendered should consider the socio-economic circumstances of the farmers such as resource base and experience.

The effect of family size on efficiency is mainly justified on the ground that those farmers with big family sizes can better manage their crops. This was again based on the assumption that there is strong correlation between the work force (i.e. economically active members of the family) and family size. Results of this study indicated there is a negative relationship between family size and technical efficiency though it is not statistically significant. This result is in fact related to the findings of MULAT DEMEKE (1989). However, similar justification should not be given to this situation, as farmers may have irrigated farms under other crops that the family labor is engaged on.

5 Summary and Conclusions

The central theme of this study was that efficient utilization of resources enhances productivity of irrigated farms. The research questions: are the farmers efficient? and what are the causes for inefficiency? were the stepping stones for this study. If inefficiencies exist, then increasing the efficiency level would be an effective means of increasing production. But, if farmers are efficient in utilizing the available resources with the existing technology, then there is a need to introduce new technologies so as to improve productivity.

This study was conducted using a sample of 80 farmers selected from four districts of Awi Zone, so as to detect where do inefficiencies exist and identify the possible causes. Following many of the previous empirical works, stochastic frontier production was employed to analyze the data. This method was used for its better ability to detect the level of efficiency through decomposing the error term into random noise and inefficiency effect.

The findings of the study indicated that farmers operating under traditional irrigation schemes are efficient; hence, improving productivity requires introduction of new technology. On the other hand, farmers producing under modern community irrigation schemes have a significant inefficiency so that the productivity of these farmers can be raised through improving their efficiency. The main causes of inefficiency were identified to be inadequate irrigation experience and discouraging price of the produce. Higher size of livestock was also identified as one of the causes of inefficiency.

According to the findings of this study farmers producing under modern community schemes can increase their production at the existing level of technology and inputs through improving efficiency. Therefore, development strategies should consider technical efficiency differences among farmers so as to effect on appropriate interventions.

The most important policy implications drawn from this study include, among others, first increasing the productivity of farmers operating under modern community irrigation schemes is possible through improving their level of technical efficiency while for those operating under traditional schemes it needs introduction of new technologies. This may be in the form of upgrading traditional irrigations so that farmers can have reliable supply of water to the crop. Secondly, unfavorable price of the produce impedes efficient production. Hence better prices enhance efficiency of farmers. This may be achieved through organizing them in marketing cooperatives. Thirdly, farmers with less irrigation experience can increase their productivity if they can acquire the skill from experienced farmers, and this may be accomplished through arranging farmers' field days.

References

Abay Asfaw and Assefa Admassie; The Impact of Education on Allocative and Technical Efficiency of Farmers: The Case of Ethiopian Smallholders; *Ethiopian Journal of Economics*; 5(1):1–26; 1996.

Abrar Suleiman; Evaluating the Efficiency of Farmers in Ethiopia; *Ethiopian Journal of Economics*; 4(2):47–66; 1995.

Aigner, D. J., Lovell, C. A. K. and Schmidt, P. J.; Formulation and Estimation of Stochastic Frontier Production Function; *Journal of Econometrics*; 6:21–37; 1977.

ANRSBPED; Annual Statistical Bulletin 2001; Amhara National Regional State Bureau of Planning and Economic Development, Bahir Dar; 2001.

Battese, G. E. and Broca, S. S.; Functional Forms of Stochastic Frontier Production Functions and Models for Technical Inefficiency Effects: A Comparative Study for Wheat Farmers in Pakistan; *Journal of Productivity Analysis*; 8:395–414; 1997.

Battese, G. E. and Coelli, T. J.; A Model for Technical Inefficiency Effects in a Stochastic Frontier Production for Panel Data; *Empirical Economics*; 20:325–332; 1995.

Coelli, T. J., Parasada Roa, D. S. and Battese, G. E.; *An Introduction to Efficiency and Productivity Analysis*; Kluwer Academic Publishers, Boston; 1998.

Day, M. M., Paraguas, F. J., Bimboa, G. B. and Regaspi, G. B.; Technical Efficiency of Tilapia Growout Pond Operations in the Philippines; *Aquaculture Economics and Management*; 4(1/2):33–47; 2000.

FAO; The State of Food and Agriculture; Food and Agriculture Organization of the United Nations, Rome; 2001.

Getu Hailu, Vira, B., Belay Kassa and Strock, H.; Technical Efficiency of Smallholder Annual Crop Production in Moisture Stress Area of Eastern Oromiya of Ethiopia: a Stochastic Frontier Analysis; *Ethiopian Journal of Agricultural Economics*; 2(2):19–31; 1998.

Gimbol, K. C., Battese, G. E. and Fleming, E. M.; Technical Efficiencies of Smallholder Cocoa Producers in Papaua Newguineay: a Stochastic frontier Analysis; *Quarterly Journal of International Agriculture*; 34:337–357; 1995.

Kalirajan, P. K. and Shand, R. T.; Firm and Product-Specific Technical Efficiencies in a Multiple Product Cycle System; *Journal of Development Studies*; 25(1):83–96; 1988.

Mulat Demeke; *The Production Efficiency of Food Grain Producers in Ethiopia: The Case of Small Farmers in Arsi Province*; Ph.D. thesis; Department of Economics, University of Strathclyde; 1989.

Parikh, A. and Shah, M. K.; Measure of Economic Efficiency in Pakistan Agriculture; *American Journal of Agricultural Economics*; 77:675–685; 1995.

Sharif, N. R. and Dar, A. A.; An Empirical Study of the Patterns and Sources of Technical Inefficiency in Traditional and HYV Rice Cultivation in Bangladesh; *Journal of Development Studies*; 32:612–629; 1996.

Sriboonchitta, S. and Wiboonpongse, A.; *On the Estimation of Stochastic Production Frontiers with Self-Selectivity: Jamise and Non-Jamise Rice Production in Thailand*; School of Economics, Chiang Mai, Thailand; 2000.

Wharton, C. R.; Education and Agricultural Growth: The Role of Education in Early Stage Agriculture; *Education and Economic Development*; 202–228; 1965.

Xu, X. and Jeffery, S.; Efficiency and Technical Progress in Traditional and Modern Agriculture: Evidence from Rice Production in China; *Journal of the International Association of Agriculture Economists*; 18(2):156–161; 1998.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 106, No. 1, 2005, pages 71–77

Effect of different types and doses of nitrogen fertilizers on yield and quality characteristics of mushrooms (*Agaricus bisporus* (Lange) Sing) cultivated on wheat straw compost

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Abstract

The most important prerequisite for a successful mushroom production is a high-quality compost substrate. For the present study wheat straw was used as bulk ingredient for the compost substrate preparation. In order to improve the C/N ratio and to accelerate the composting process, all substrate formulas need the addition of nitrogen-rich supplements at the outset of composting. Besides organic nitrogen sources, inorganic nitrogen supplements are also applied, when high-carbohydrate bulk ingredients are used. In the present work four different nitrogen fertilizers (urea (46 % N), ammonium nitrate (33.5 % N), calcium ammonium nitrate (26 % N) and ammonium sulfate (21 % N)) in three doses were applied as nitrogen sources and the effect on yield and some quality characteristics (cap weight, stalk weight, cap diameter, stalk diameter and stalk length) was investigated. The fertilizer application had only an unimportant effect on the cape diameter, which is an important characteristic for the classification of mushrooms, but had a stronger effect on the stalk length, which is also important for the classification. The highest dose of calcium ammonium nitrate produced the significant highest yield at the same time this variant also resulted in good results regarding the investigated quality characteristics.

Keywords: *Agaricus*, mushroom, compost, N-fertilizers

1 Introduction

To prepare high-quality compost is the most important factor for a successful mushroom production. *Agaricus bisporus* is a secondary decomposer, which means that bacteria and other fungi have first to break down the raw materials of the substrate before the mushroom can grow (Volk and Ivors, 2001). In the ready compost substrate the inactivated microorganisms serve as an important nutrient source for the mushrooms (Beyer, 2003; Schnitzler, 2003).

Straw-bedded horse manure supplies a very suitable basis for growing mushrooms and is the most used substrate for cultivating mushrooms in Europe as well as in the USA and

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Canada. However, horse manure is not always and everywhere available in a sufficient quantity and quality to an acceptable price. Therefore horse manure is often partly or completely replaced by chicken manure. Sheep, cattle and pig manure is only of little importance for mushroom growing, as these manures do not supply a suitable basis for the fermentation of the substrate. Medicament residues of a former treatment of the animals can also have a negative effect on the composting process. For a long time there are attempts to work only with straw substrates (SCHNITZLER, 2003).

The aim of the mushroom substrate preparation is to produce a medium that is nutritionally sufficient and selective for the mushroom mycelium growth. For an undisturbed run of the composting process, besides a sufficient supply with water, oxygen and nutrients, a balanced C/N ratio must be guaranteed. Therefore, all compost formulas require besides the conditioning agent gypsum the addition of nitrogen-rich supplements (BEYER, 2003). The values given in the references for the desirable nitrogen content at the outset of composting vary between 1.5 % and 2.0 % computed on dry weight basis (VEDDER, 1978; CHANG and HAYES, 1978; BOZOK, 1987; BEYER, 2003). Besides protein-rich seed meals, like soybean meal, cottonseed meal and brewer's grain, commercial fertilizers are used as nitrogen supplements when high-carbohydrate bulk ingredients are used (BEYER, 2003).

For the present work wheat straw was used as bulk ingredient for the compost substrate preparation. Wheat straw consists of 92.5 % total dry matter, 3.9 % protein, 1.5 % fat, 36.7 % fiber, 41.9 % N-free extract, 8.3 % total minerals, 0.21 % Ca, 0.07 % P, 0.62 % N and 0.79 % K (CHANG and MILES, 1989). Wheat straw is one of the most uncomplicated materials with which to work (STAMETS, 2000). The nitrogen content of wheat straw based compost however, is too low to meet the need of the compost microorganisms for an optimal growth and reproduction. For a successful composting and therefore for a successful mushroom production a readily available form of nitrogen must be added to the substrate at the outset of composting.

The aim of the present investigation was to find out, how the addition of different N -fertilizers in different doses as N-supplement affects the yield and some quality characteristics of the mushrooms.

2 Materials and Methods

The research was conducted at the Mushroom Production Facility of Çanakkale Onsekiz Mart University, Turkey. Four different fertilizer types: Urea (with 46% N), AN (ammonium nitrate with 33,5% N), CAN (calcium ammonium nitrate with 26 % N) and AS (ammonium sulfate with 21 % N), were applied in three different doses (60 g N/bag, 70 g N/bag and 80 g N/bag) as nitrogen sources. Five replications for each treatment, making up a total of 60 plots, were arranged in a randomized complete block design.

The different composts were prepared according the composting timetable as seen in table 1.

The ready composts (ammonia concentration under 0.05 percent) were put in 10 kg black polyethylene bags. To initiate the mycelium growth the bags were kept in a

Table 1: Composting timetable

Day	*Application*
- 4	Bales of wheat straw (316 kg for 60 bags) were opened and watered (water amount calculated with 2,5 t water/t wheat straw).
0	Dry parts of the straw were watered, mixed with bran (0,742 kg/bag). The N doses for each fertilizer variant (60 g N/bag, 70 g N/bag, 80 g N/bag) were added separately and composts were pressed and piled again.
5	Piles were broken up, bran (0,742 kg/bag) and molasses (0,210 kg/bag) were added. Composts were mixed, pressed and piled (1. turn over).
9	Piles were broken up, dry parts were watered and gypsum (0,316 kg/bag) was added. Composts were mixed and piled again but without pressing (2. turn over).
12	Compost piles were aerated and piled again without pressing (3. turn over).
14, 16, 18, 20 and 22	Compost piles were turned over for the 4th, 5th, 6th, 7th, 8th time.
23	Composts were pasteurized.
26	Composts were aerated and mixed.
29	Inoculation of the aerated composts with 60 g mycelium/bag.

production room with a temperature of 20 to 25 °C and moisture content of 85 to 90 %. When a complete colonization of the composts with mycelium was achieved, pasteurized peat from Bolu Yeniçag, Turkey was added as a surface layer (4 cm), to promote mushroom formation. A few days later the room temperature was decreased to 16 to 18 °C and two weeks later the ventilation of the room was increased. During the whole run of the experiment, cultural and technical procedures were applied according to the instructions of Erkel (1993).

During the picking period (breaks) the mushrooms were twisted out before the veil broke and the following data were recorded daily, corresponding with the work of İlbay and Ağaoğlu (1996): Number of mushrooms per bag; yield (g/bag); average cap weight (g/mushroom); average cap diameter (mm); average stalk weight (g/mushroom); average stalk diameter (mm); average stalk length (mm).

Data were analyzed using ANOVA and the differences among the treatment means were separated by the Duncan's multiple range test (SAS, 1996). Due to wet rottenness no yield was obtained from the 80 g N/bag urea application, therefore, statistical analysis was done only with 11 treatments.

3 Results

The results of this investigation are given in the tables 2 (a–g). The effects of treatments were found significant at the 5% level.

3.1 Number of Mushrooms

The results presented in table 2 (a) show significant differences in the number of mushrooms/bag, due to the applied fertilizer type and the interaction of fertilizer type and dose. In the mean of the fertilizer doses CAN resulted the significant highest number of mushrooms/bag and AS the significant lowest. Urea, CAN and AN application show a correlation between increasing dose of fertilizer and the number of mushrooms. The number of mushrooms increased with increasing dose of urea and CAN, but decreased with increasing dose of AN.

3.2 Yield (g/bag)

Table 2 (b) shows a statistically significant effect of the fertilizer type, the fertilizer dose and the fertilizer type/dose interaction on the yield. In the mean of the fertilizer doses, the CAN application produced the significant highest yield and the AS application the lowest. Regarding the interaction of fertilizer type and dose, the significant highest yield was obtained with the highest dose of CAN. Parallel with the number of mushrooms yield increased with increasing dose of urea und CAN and decreased with increasing dose of AN (Tables 2 a and b).

3.3 Average Cap Weight (g)

In the mean of fertilizer doses, the application of urea produced the significant highest average cap weight and the CAN application the lowest. The highest cap weight was obtained with the lowest dose of urea and the lowest with the medium dose of CAN (Table 2 c).

3.4 Average Stalk Weight (g)

The effect of the fertilizer type, the fertilizer dose and the interaction of fertilizer type and dose resulted in significant different stem weights. The single values of the fertilizer/dose interaction vary considerably (Table 2 d).

3.5 Average Cap Diameter (mm)

The effect of the fertilizer type, the dose and the fertilizer/dose interaction on the cap diameter was relatively low, and the differences are only partly statistically significant (Table 2 e).

3.6 Average Stalk Diameter (mm)

In the mean of the fertilizer doses, the application of AS resulted in the significant smallest and the CAN application in the significant greatest average stalk diameter (Table 2 f).

3.7 Average Stalk Length (mm)

In the mean of the fertilizer types, the highest fertilizer dose resulted in the significant shortest average stalk length. In the mean of the doses all fertilizer types produced significant different stem lengths. With regard to the fertilizer/dose interaction, the stem length decreased with increasing dose of urea, AN, and CAN, but the application of AS caused the opposite reaction (Table 2 g).

Table 2: Number of mushrooms per bag

Doses (g N/bag)	*Fertilizer type*				*Mean*
	Urea	*AN*	*CAN*	*AS*	
(a) *Number of mushrooms per bag*					
1 (60)	36 ^{g}	111 ^{c}	80 ^{f}	17 ^{h}	61 ^{B}
2 (70)	81 ^{f}	104 ^{d}	123 ^{b}	4 ^{j}	78 ^{A}
3 (80)	-	92 ^{e}	145 ^{a}	12 ^{i}	83 ^{A}
Mean	58 ^{C}	102 ^{B}	116 ^{A}	11 ^{D}	74
(b) *Yield per bag (g)*					
1 (60)	825 ^{g}	2177 ^{b}	1565 ^{g}	262 ^{h}	1207 ^{C}
2 (70)	1706 ^{d}	1890 ^{c}	1846 ^{c}	61 ^{j}	1376 ^{B}
3 (80)	-	1638 ^{e}	2540 ^{a}	204 ^{i}	1461 ^{A}
Mean	1266 ^{C}	1902 ^{B}	1984 ^{A}	175 ^{D}	1348
(c) *Average cap weight (g)*					
1 (60)	17.05 ^{a}	12.48 $^{e-g}$	13.79 ^{cd}	12.33 ^{fg}	13.91 ^{A}
2 (70)	15.32 ^{b}	13.03 $^{d-e}$	11.03 ^{h}	14.02 ^{c}	13.35 ^{B}
3 (80)	-	13.87 ^{cd}	11.96 ^{g}	13.39 $^{c-e}$	13.07 ^{B}
Mean	16.19^{A}	13.13 ^{B}	12.26 ^{C}	13.25 ^{B}	13.44
(d) *Average stem weight (g)*					
1 (60)	7.21 ^{a}	7.15 ^{a}	5.90 ^{b}	3.28 ^{g}	5.89 ^{A}
2 (70)	5.80 ^{b}	5.10 ^{d}	4.01 ^{f}	2.23 ^{h}	4.29 ^{C}
3 (80)	-	3.96 ^{f}	5.58 ^{c}	4.39 ^{e}	4.64 ^{B}
Mean	6.51 ^{A}	5.40 ^{B}	5.16 ^{C}	3.30 ^{D}	4.94
(e) *Average cap diameter (mm)*					
1 (60)	40.2 ^{b}	36.7 ^{cd}	39.6 ^{b}	36.6 ^{cd}	38.3 ^{B}
2 (70)	36.1 ^{cd}	43.0 ^{a}	37.4 ^{c}	41.2 ^{ab}	39.4 ^{A}
3 (80)	-	37.4 ^{c}	35.0 ^{d}	41.7 ^{ab}	38.0 ^{B}
Mean	38.2 ^{C}	39.0 ^{AB}	37.3 ^{C}	39.8 ^{A}	38.6
(f) *Average stem diameter (mm)*					
1 (60)	22.6 ^{ef}	25.9 ^{bc}	27.2 ^{b}	13.2 ^{g}	22.2 ^{B}
2 (70)	22.6 ^{ef}	25.0 ^{cd}	23.6 ^{de}	20.8 ^{f}	23.0 ^{B}
3 (80)	-	21.4 ^{f}	31.1 ^{a}	24.5 ^{cd}	25.7 ^{A}
Mean	22.6 ^{C}	24.1 ^{B}	27.3 ^{A}	19.5 ^{D}	23.6
(g) *Average stem length (mm)*					
1 (60)	26.3 ^{b}	28.8 ^{a}	22.9 ^{c}	16.5 ^{g}	23.6 ^{A}
2 (70)	20.2 ^{e}	27.4 ^{b}	22.6 ^{cd}	21.8 ^{cd}	23.0 ^{A}
3 (80)	-	19.5 ^{ef}	18.5 ^{f}	21.5 ^{d}	19.8 ^{B}
Mean	23.3 ^{B}	25.2 ^{A}	21.3 ^{C}	19.9 ^{D}	22.2

4 Discussion and Conclusions

Yield increased with increasing number of mushrooms (Table 2 a and b). The highest number of mushrooms and therefore the highest yield was obtained with the highest dose of CAN. The second highest yield was obtained with the lowest dose of AN. As in the medium dose CAN and AN application yielded no significant yield difference, this result suggests that in the highest fertilizer dose the lime content of CAN resulted in a positive effect. The yield difference between the highest and the second highest yield is with 363 g/bag comparatively high, but the additional costs arising from the application of the higher fertilizer dose are with € 0.02/bag relatively low. The application of urea yielded comparatively low yields, but the application of AS produced only very unsatisfactory yields. Similar results were found in previous studies (İLBAY and AĞAOĞLU, 1996; ÖZŞIMŞIR and ARIN, 1996; GÜNAY and A. UZUN, 1996; ZÜLKADIR *et al.*, 1996).

The cap is the preferred part of the mushroom, therefore mushrooms with high cap weights and low stalk weights are desirable. In the mean of the doses the CAN application resulted in a significant lower cap weight than the AN application, but the lowest dose of AN (second highest yield), produced no significant higher cap weight than the highest dose of CAN (highest yield) (Table 2 c). With regard to the stalk weight, the highest dose of the CAN application resulted in a considerable lower stalk weight then the lowest dose of the AN application (Table 2 d).

Even if the differences are partly statistically significant, the different fertilizer applications had only an unimportant effect on the cap diameter. According to the provisions of the Commission Regulation of the European Community (binding since 1 January 2003) for cultivated mushrooms size is determined by the maximum diameter of the cap and the length of the stem (EC, 2002). According to this regulation the minimum cap diameter must be at least 15 mm for closed, veiled and open mushrooms. The average cap diameter of all fertilizer applications of this study, was considerably higher then this limit (Table 2 e). The values of the cap diameters of all fertilizer applications varied lesser than the provisions of the EC Regulation for closed, veiled and open mushrooms allow, if they are market as 'Extra Class' or Classes I and II and the terms 'small' or 'medium' are indicated (specified size ranges for small mushrooms 15-45 mm; for medium mushrooms 30-65 mm).

The highest CAN application (highest yield) produced the greatest stalk diameter, but regarding the stem length (Table 2 f), which is important for the classification, this application produced with in the mean 18,5 mm (1/2 of cap diameter) a comparatively low stem length (Table 2 g). According to the Commission Regulation the maximum stem length (closed, veiled and open mushrooms) must not exceed 2/3 of the cap diameter, when the mushrooms are uncut and 1/2, when the mushrooms are cut (EC, 2002). As in the mean the stalk length of the highest CAN application did not exceed 1/2 of the cap diameter, only very few stalk scraps will be obtained, even if the stalks will be trimmed before the mushrooms are marketed.

The highest doses of CAN (80 g N/bag) produced not only the significant highest yield, but also regarding the most important quality characteristics good results. Therefore,

with regard to this study, the application of CAN in a corresponding dose is to be recommended, if inorganic nitrogen sources will be used to increase the nitrogen content at the outset of the mushroom compost preparation.

References

BEYER, D. M.; *Basic Procedures for Agaricus Mushroom Growing*; Penn State University, University Park, Pennsylvania; 2003.

BOZOK, K.; Mantar Üretim Tekniği; E.Ü. Ziraat Fakültesi Yayınları No. 489. Ofset Basimevi, Bornova, İzmir; 1987.

CHANG, S. T. and HAYES, W. A.; *The Biology and Cultivation of Edible Mushrooms*; Academic Press Inc., New York; 1978.

CHANG, S. T. and MILES, P. G.; *Edible Mushrooms and Their Cultivation*; CRC Press, Boca Raton, Florida; 1989.

EC; Commission Regulation (EC) No 982/2002 of 7 June 2002 laying down the marketing standards for cultivated mushrooms; OJ L. 150, 45-49; 2002.

ERKEL, I.; Kültür Mantarı Yetiştiriciliği; Yalova; 1993.

GÜNAY, A. and A. UZUN, A.; Buğday Sapı ve Tavuk Gübresinin Esas Alındığı Değişik Yetiştirme Ortamlarının Mantarın Verim ve Kalitesi Üzerine Etkileri; Türkiye 5. Yemeklik Mantar Kongresi, 5-7 Kasım, Yalova; 1996.

İLBAY, M. E. and AĞAOĞLU, S.; Kültür Mantarı Yetiştiriciliğinde Değişik Yetiştirme Ortamlarının Verim ve Kaliteye Etkisi Üzerinde Araştırmalar; Türkiye 5. Yemeklik Mantar Kongresi, 5-7 Kasım, Yalova; 1996.

ÖZŞIMŞIR, L. and ARIN, L.; Farklı Örtü Toprağı Karışımlarının Mantar Verim, Erkencilik ve Kalitesine Etkisi; Türkiye 5. Yemeklik Mantar Kongresi, 5-7 Kasım, Yalova; 1996.

SAS; *SAS User Guide: Statistic*; Statistical Analysis Systems Institute Inc., Cary, NC; 1996.

SCHNITZLER, W. H.; Ökologie und Biotechnologie von Kulturspeisepilzen; Vorlesungs-Skript, 3. Auflage. Lehrstuhl für Gemüsebau Technische Universität München-Weihenstephan; 2003.

STAMETS, P.; *Growing Gourmet and Medicinal Mushrooms; Third edition*; Ten Speed Press, Berkley, Toronto; 2000.

VEDDER, P. J. C.; *Modern Mushroom Growing*; Grower Books; 50 Doughty Street, London; 1978.

VOLK, P. and IVORS, K.; Tom Volk's Fungus of the Month for April 2001; University of Wisconsin-La Crosse; 2001.

ZÜLKADIR, A., DURSUN, A. and ALAN, R.; İki Farklı Kompost Reçetesinin Örtü Toprağı Aşamasında Değişik Oranlarda Uygulanan Buğday ve Misir Ununun Kültür Mantarında Verim ve Kalite Unsurlarına Etkisi; Türkiye 5. Yemeklik Mantar Kongresi, 5-7 Kasım, Yalova; 1996.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 106, No. 1, 2005, pages 79–85

СТЕПЕНЬ АДАПТИВНОСТИ ЛИАН (*Parthenocissus quinquefolia* (L.), *Campsis radicans* (L.)) К УСЛОВИЯМ

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В условиях все более интенсивного использования природных ресурсов, увеличения численности населения и урбанизации, мы оказались перед неопровержимым фактом ухудшения условий окружающей среды, особенно в крупных городах и промышленных центрах.

В настоящее время проводятся разносторонние научные и практические исследования по борьбе с загрязнением атмосферного воздуха. С одной стороны, эти исследования направлены на сокращение наносимого загрязнителями ущерба живым организмам, с другой - на максимальное сокращение поступления промышленных отходов в атмосферу. Особенно, это важно для растений, которые по сравнению с животными и человеком, более чувствительны к таким широко распространенным загрязнителям воздуха, как двуокись серы и азота (SO_2, NO_2) фтористые соединения и хлористый водород (Гудериан, 1979).

Уже первые исследователи подчеркивали разную степень устойчивости отдельных видов растений к газам. Реакция растений может быть очень разнообразная, от незначительного поврежденного до полной их гибели. Более активно вредные вещества могут действовать непосредственно на их ассимиляционный аппарат (Красинский, 1950; Николаевский, 1964 и др.), а также и через почву - на корневую систему (Рябинин, 1987; Кулагин, 1974).

На клеточном и субклеточном уровне воздействие токсического агента, чаще всего скрыто от визуального наблюдения, его можно обнаружить с помощью микроскопических и других методов. Т.Келлер (Keller, 1984), говоря о воздействии газодымовых выбросов на деревья предлагает понятие "латентные повреждения", а Rabe (1982) - "тонкие повреждения".

В истории биоиндикации, скрытые повреждения привлекли к себе внимание морфологические изменения растений в ответ на антропогенное воздействие. Различают макро- и микроскопические изменения. Рассмотрим микроскопические изменения, к которым относятся:

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(1) изменение размеров клеток, например, уменьшение клеток эпидермы листа как реакция на газообразное загрязнение (Николаевский, 1979);

(2) изменения степени ксероморфизма листа как следствие газообразных выбросов, форма приспособления к ним (Николаевский, 1979; Kutschera Mitter et al., 1982, цит.по Вайнеру, 1988), которая выражается в увеличении числа устьиц, толщины кутикулы, густоты опушения, толщины листа и степени суккуленстности (отношение сухой/сырой вес).

Микроскопические симптомы появляются обычно раньше макроскопических (Stolzer, 1980). Однако, анатомические исследования, обычно слабо используемые для ранней индикации, способствовали пониманию процесса некротизации и морфологическому выявлению типов растений, устойчивых к газообразным выбросам.

В предыдущих работах нами проводились исследования по определению устойчивости двух представителей местной флоры *Jasminum officinale* L.[3] (сем. *Oleaceae*) и *Polygonum baldshuanicum* Rgl. (сем. *Polygonaceae*) в условиях промышленного загрязнения ТЭЦ (г.Душанбе) (Эргашева, 1995).

Результаты анатомических исследований показали. Что эти виды лиан неодинаково проявляют степень устойчивости. *J. officinale* показал себя как наиболее приспособленный к условиям городской среды и промышленного загрязнения (наличие хорошо выраженной кутикулы и развитой палисадной паренхимы - отношение толщины палисадной к губчатой паренхиме составило 1:1), а *P. baldshuanicum* весьма чувствителен к промышленному загрязнени. В районе действия ТЭЦ его листья сильно повреждались и происходило усыхание молодых побегов.

Задачей настоящего исследования явилось изучение структурных особенностей двух перспективных видов лиан в условиях города.

Материалы и методика

Исследовались два представителя флоры Северной Америки: *Parthenocissus quinquefolia* (L.) Planch. и *Campsis radicans* (L.) Seem. Выбор таких объектов определяется тем, что эти виды в настоящий момент используются в озеленении города Душанбе, но, конечно же не так широко как хотелось бы, в основном в дошкольных учреждениях, во дворах и очень редко для озеленения кофетериев и баров.

Работа выполнялась на территории Центрального ботанического сада Академии наук Республики Таджикистан (ЦБС) и в районе проспекта Шерози (Цирк), где отмечается наибольшее количество транспорта и близость таких промышленных предприятий как Таджикатлас, Текстильный комбинат, ТЭЦ и другие.

Согласно данным анализа основных параметров погоды (температура, осадки, влажность воздуха и т.д.), за период исследования, наиболее лимитирующими факторами в районе исследования явились: в зимний период - низкая температура

[3] *Jasminum officinale* - редкий и исчезающий вид во флоре Таджикистана, занесен в Красную книгу СССР (1984).

воздуха и отсутствие постоянного снежного покрова: в летний период - дефицит влаги, обусловленный высокими температурами и низкой относительной влажностью воздуха.

Изучение анатомического строения листа проводили по схеме-описанию, представленной М.С.Гзыряном (1959). Исследованный материал фиксировался в 75° спирте. Изготовлялись временно-постоянные препараты, основанные на желатин-глицерине. Просмотр объектов проводился под микроскопом БИОЛАМ Р-14 с бинокулярной насадкой 1.5^{X}, и с применением рисовального аппарата РА-7У. Измерения проводились с помощью окуляр-микрометра визированного на объект-микрометр. Статистическая обработка (нахождение среднего арифметического и ошибки) проводились по методике Г.Ф. Лакина (1980).

Результаты исследования

Campsis radicans (L.) Seem. (сем. *Bignoniaceae*) - листопадная лиана из Северной Америки. В ЦБС интродуцирована в 60-е годы. Взбирается по опоре на высоту 15-20 м, прикрепляется к ней с помощью воздушных корешков. Листорасположение супротивное. Листья сложные непарноперистые. По морфологическому строению листья отличаются в зависимости от условий произрастания (табл. 1). В условиях техногенного загрязнения листья приобретают ярко-зеленую или желтовато-зеленую окраску, а ЦБС лист темно-зеленый.

Таблица 1: Морфологическая характеристика листа *C.radicans* в разных экологических условиях

Место произрастания	*Длина главного черешка, см*	*Верхняя листовая пластинка*		*I пара листочков*			*Количество пар*	*Окраска*
		Длина	*Ширина*	*Черешок*	*Длина*	*Ширина*		
Пр.Шерози (опыт)	36.0	12.0	6.2	0.8	7.8	6.2	6	Желто зелена
ЦБС (контроль)	38.0	9.0	7.1	2.0	11.2	7.1	5	Темно зеленая

Листочки по краю пильчатые, на вершине заостренные, у основания клиновидные, сверху голые, снизу опушенные. Декоративность проявляется в период цветения, которое начинается в конце мая и продолжается до середины августа. Цветки ярко-оранжевого цвета, воронковидные, длиной 8-9 см, собраны в верхушечных кистях.

К почвам малотребователен. Растет быстро.

Анатомическое строение листьев C.radicans в контроле и опыте весьма сходны. Различия между ними в основном количественного, чем качественного характера (табл. 2).

Верхняя эпидерма однослойная, клетки ее таблитчатой формы, плотносомкнутые (у опытных растений клетки сильно вытянуты в тангентальном направлении), с наружи с выпуклыми утолщенными оболочками (особенно у опытных растений),

покрыты блестящей кутикулой. Палисадная паренхима представлена 2(3) слоями (опыт) и 1(2) слоями (контроль) тонкостенных, плотносомкнутых, цилиндрической формы клеток, содержащих многочисленные хлоропласты. В среднем длинная ось клеток палисадной паренхимы составляет 25,6±0,75 мкм, а короткая - 12,2±0,48 мкм (контроль). Губчатая паренхима 4-5(6)-слойная, клетки ее почти округлые, с небольшими межклетниками. Сосудисто-волокнистые пучки замкнутые, коллатеральные. Сосуды мелкие, с утолщенными стенками и угловатой полостью. Клетки нижней эпидермы с тонкими сильно извилистыми стенками: устьица аномоцитного типа, направленные в разные стороны. Длина устьиц почти в два раза превосходит ширину, количество их на 1 мм2 составляет 171-228 (контроль) и 114-228 (опыт) штук. Сопровождающих клеток устьиц 4-5, по очертанию они не отличаются от остальных клеток нижней эпидермы.

Толщина листовой пластинки в условиях ЦБС составляет 158,0±2,69 мкм, а в условиях городской среды - 113,0±4,95 мкм.

Таблица 2: Количественно-анатомические показатели пластинки листа *C. radicans* в разных экологических условиях произрастания

Показатели в мкм	*ЦБС (контроль)*	*Пр.Шерози (опыт)*
Толщина пластинка листа	158,0±2,69	113,0±4,95
Толщина мезофилла	125,6±2,16	85,0±4,95
Верхняя эпидерма:		
Высота	20,2±0,80	14,4±0,26
Ширина	28,2±2,53	27,2±2,58
Кол-во клеток на 1 мм^2	1600-1828	971-1142
Палисадная паренхима:		
Число слоев	2(3)	1(2)
Длинная ось	25,6±0,75	42,2±1,58
Короткая ось	12,2±0,48	12,8±0,48
Нижняя эпидерма:		
Высота	12,2+0,49	11,6+0,97
Ширина	15,2±0,33	14,4±0,26
Устьица		
Длина	27,8±0,53	25,0±0,89
Ширина	13,8±0,54	14,8±0,32
Количество на 1 мм^2	171-228	114-228

Проведенные анатомические исследования строения листа *C.radicans* (контрольных и опытных), показали сходство в их строении. Различия в основном количе-

ственного, чем качественного порядка. Листья контрольных растений менее утолщены, клетки верхней эпидермы покрыты тонким слоем кутикулы, палисадная паренхима фактически представлена 1 слоем клеток, губчатая паренхима мелкоклеточная. Волоски встречаются только на нижней стороне листа и в основном прикреплены к жилкам. Кроме этого на нижней стороне эпидерме, в палисадной и губчатой паренхиме отмечаются в большом количестве жировые клетки.

О действии атмосферных загрязнителей можно судить и по наличию отдельных некротических клеток (побурение оболочек и содержимого клеток), хотя внешне листья этих растений чаще остаются неповрежденными. Это так называемые "скрытые повреждения". Вначале повреждаются замыкающие клетки устьиц, а затем соседние с ними эпидермальные клетки и уже потом - клетки губчатой паренхимы, реже клетки палисадной ткани.

Parthenocissus quinquefolia (L.) Planch. (сем. *Vitaceae*) - вьющаяся лиана, поднимающаяся по опоре до высоты 15-20 (25) м. Происходит из восточных районов Северной Америки. Листья сложные. На черешках длиной до 6-8 см, пальчатые, состоят из 5 эллиптических или обратнояйцевидных, длиной 4-12 см листочков с остроконечной и зубчатой по краю верхушкой и клиновидным, сбегающим на короткий черешок основанием. Листья голые, сверху темно-зеленые и тусклые, снизу сизоватые, окрашивающиеся осенью в красно-фиолетовые тона. Цветет обычно в июле-августе, плоды созревают в сентябре-октябре.

При изучении анатомического строения листа в условиях ЦБС и городской среды выявлено, что листья имеют фактически сходное строение и отличия представлены лишь количественного характера (табл. 3).

Лист имеет дорсивентральное строение. Верхняя эпидерма однослойная, толстостенная, длина ее клеток 50,8±2,40 мкм, а высота 22,6±1,16 мкм. Палисадная паренхима однослойная. Клетки палисадной ткани тонкостенные в контроле и более сомкнуты, а в опыте - сильно разрыхлены и имеют слегка неправильную форму. В среднем длинная ось клетки равняется 58,0±0,81, а короткая ось - 19,0±0,77 мкм. Губчатая паренхима состоит из клеток разнообразной величины округлой и слегка неправильной формы с большим количеством межклеточного пространства. В мезофилле отмечается большое количество проводящих пучков содержащих друзы и рафиды оксалата кальция. Нижняя эпидерма однослойная, тонкостенная, длина клеток составляет 37,2±1,01, а высота 19,0±0,77 мкм. Устьица аномоцитного типа. Длина устьиц равняется 28,8±0,32 и ширина 23,8±1,01 мкм. Число устьиц колеблется в пределах от 100 до 171 на 1 мм2. Сопровождающих клеток 4(5), по очертанию они не отличаются от остальных клеток нижней эпидермы. Толщина листовой пластинки - 167,6±4,01 мкм, мезофилла - 137,4±3,87 мкм. Листья опытных растений *P.quinquifolia* по анатомическому строению существенно не отличаются от растений произрастающих в условиях городской среды. Они характеризуются лишь менее утолщенной листовой пластинкой, наличием на нижней эпидерме вдоль главной жилки и проводящих пучков 4-5-клеточных волосков, мелкоклеточностью клеток верхней эпидермы, большим количеством устьиц на

Таблица 3: Количественно-анатомические показатели пластинки листа *P. quinquifolia* в разных экологических условиях произрастания

Показатели в мкм	*ЦБС (контроль)*	*Пр.Шерози (опыт)*
Толщина пластинка листа	167,6±4,01	144,4±2,25
Толщина мезофилла	137,4±3,87	112,6±4,20
Верхняя эпидерма:		
Высота	22,6±1,16	19,6±1.16
Ширина	50,8±2,40	45,6±1.22
Кол-во клеток на 1 мм^2	457-685	685-971
Палисадная паренхима:		
Число слоев	1	1
Длинная ось	58,0±0,81	44,8±0.64
Короткая ось	19,0±0,77	14,8±0,32
Нижняя эпидерма:		
Высота	19,0±0,77	8,6±0,40
Ширина	37,2±1.01	28,8±1.49
Устьица		
Длина	28,8±0,32	29,0±1.22
Ширина	23,8±1.01	20,8±0,80
Количество на 1 мм^2	100-171	171-285

нижней эпидерме и наличием некротических клеток в основном в губчатой паренхиме и частично в палисадной.

Выводы

Результаты анатомического исследования листьев двух перспективных для озеленения видов лиан (*P. quinquifolia* и *C.radicans*)позволяет сделать важный вывод о том, что в условиях городской среды, где в атмосферном воздухе присутствуют токсические вещества от общественного транспорта (NO, SO_2, CO, фармальдегид, бенз(а)пирен, сажа, тяжелые металлы) происходит нарушение соотношения различных тканей листа, изменяется форма, размеры и количество клеток, составляющие ту или иную ткань листа, т.е. признаки количественного порядка. Которые позволяют рассматривать эти признаки как структурное приспособление лиан к экстремальным условиям существования. О последствиях действия атмосферных загрязнителей можно судить по проявлению ксероморфных признаков, а также по наличию отдельных некротических клеток в мезофилле листа. При этом визуальные наблюдения показывают, что внешне листья чаще всего остаются неповрежденными.

Таким образом, отсутствие существующих признаков повреждения листьев исследованных видов позволяет отнести их к устойчивым породам, которые успешно могут быть использованы при озеленении городов и промышленных центров Республики Таджикистан.

Резюме

Приводятся результаты анатомических исследований листьев лиан (*Parthenocissus quinquefolia* (L.), *Campsis radicans* (L.)) в условиях городской среды. Выевлено, что лианы в условиях загрязнения проявляют признаки ксерофитизации. О действии загрязнения можно судить по некротическим клеткам в мезофилле листа. По визуальным наблюдениям листья не имеют признаков повреждения.

Degree of Adaption of Lianas (*Parthenocissus quinquefolia* (L.) and *Campsis radicans* (L.)) **to the Environmental Conditions of Towns**

G. N. Ergaschewa and W. Drauschke

Abstract

Results of anatomic investigations are discussed, being carried out at leaves of lianas (*Parthenocissus quinquefolia* (L.) and *Campsis radicans* (L.)), growing under environmental conditions of towns.

It could be found from the result, that xerographic phenomenons are reflecting the environmental conditions in towns. The effects of environmental pollution can be found at necrotic cells in the mesophyll of leaves.

Demages of the leaves could be found by only visual investigations of the leaves.

Keywords: environmental pollution, environmental demages, lianas, climbers, Middle Asia, Dushanbe, climatic data, botanical investigations

Литература

1. Вайнерт Э. Биоиндикация загрязнений наземных экосистем. - М., Мир, 1988, 350 с.
2. Гзырян М.С. К методике анатомического изучения листьев двудольных растений .// Тр.Инст.ботаники.АН АзербССР, Баку, 1959, т.21, с. 159-165.
3. Гудериан Р. Загрязнение воздушной среды. - М.,Мир, 1979, 200 с.
4. Keller T. "Phil. Trems. Ray. Soc. London ", 1984, D 305, N 1124, p. 317-325.
5. Красинский Н.П. Дымоустойчивость растений и дымоустойчивые ассортименты. - М.,Наука, 1950, с. 9-109.
6. Красная книга СССР. - М., Лесная промышленность, 1984, т.2, с.267.
7. Кулагин Ю.З. Древесные растения и промышленная среда. - М., Наука, 1974, 250 с.

8. Лакин Г.Ф. Биометрия. - М., Высшая школа, 1990, 352 с.

9. Николаевский В.С. Влияние сернистого ангидрида на древесные растения в условиях Свердловской области. // в кн.: Охрана природы на Урале. Свердловск, 1964, с. 123-132.

10. Николаевский В.С. Биологические основы газоустойчивости растений. - Новосибирск, Наука, 1979, 592 с.

11. Рябинин И.А. и др. Об устойчивости почвенной биоты к загрязнению сернистым ангидридом.//Межд.Всесоюзн.конф. Влияние промышленных предприятий на окружающую среду. Звенигород, 1985. - М., 1987, с. 279-284.

12. Эргашева Г.Н. Структурные и функциональные особенности некоторых кустарниковых лиан в Таджикистане. - Автореф. канд.диссер. Душанбе, 1995, 26 с.

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 106, No. 1, 2005, pages 87–93

Buchbesprechungen – Book Reviews

M. Niaounakis und C. P. Halvadaki; 2004

Olive-Mill Waste Management Literature Review and Patent Survey

Typothito- Geoge Dardanos Publications, Athen. 430 pages. ISBN 960-402-123-0.

From an environmental point of view olive mill waste is a problem around the Mediterranean, especially in poor communities of southern Europe and North Africa. The problems created in managing this waste have been extensively investigated during the last 50 years without finding a solution, which is technically feasible, economically viable and socially acceptable. The prevalent waste management strategy up to date has been traditional wastewater treatment processes aimed at reducing pollution loads to legally accepted levels for disposal into environmental media, mainly land and water bodies. Recently, Spain has adapted a manufacturing process for olive oil production, which minimizes the utilization of water and, therefore, of generated wastewater, the so-called two-phase olive mill extraction technique. The pollution load is, however, the same since it originates from the olives and not from the water utilized during olive processing. In view of the above, it is apparent that a new strategy for olive waste management must be adopted. With the literature review and patent survey presented in this book the authors delivering the basis for the development of new strategies.

The focus of the literature review and patent survey undertaken by the authors is to evaluate the existing technologies and to develop environmental criteria for reusing and/or disposing olive-mill wastes in general and wastewater in particular. The prior art is critically and extensively reviewed - more than 1000 references are cited and commented upon. A substantial part of the literature collection consists of patents. The book is very informative and a useful tool for all experts dealing with waste management und environmental problems especially around the Mediterranean.

Peter Wolff, Witzenhausen

S. Höynck; 2003

Motivation of farmers in large-scale irrigation systems - Implications for performance Assessment.

340 Seiten. Mitteilungen Lehrstuhl für Landwirtschaftlichen Wasserbau und Kulturtechnik am Institut für Städtebau, Bodenordnung und Kulturtechnik der Universität Bonn, Heft 11.

Nach einer intensiven Beschäftigung mit dem Performance Assessment großer Bewässerungssysteme kommt die Autorin in dem vorgelegten Forschungsbericht einleitend zu der Feststellung, dass die Sicht- und Verhaltensweise von Landwirten in Bezug auf die Leistungen des Managements großer Bewässerungssysteme bisher nur unzureichend berücksichtigt wurde. Sie stellte ferner fest, dass die Zielsetzung des Systemmanagements sowie die Erfüllung der Performance Standards an entscheidenden Punkten mit der Zielsetzung und Verhaltensweise der Landwirte kollidieren. Hier stellt sich die Frage wo die Ursachen für diese Diskrepanz liegen und wie ihr zu begegnen ist. Können Anreizsysteme unter Berücksichtigung bzw. Anpassung an die Motivationssituation der Landwirte nachhaltig wirken.

Die durchgeführte Fallstudie bezog sich auf das Phitsanulok Bewässerungssystem in Zentralthailand. Das Gebiet diente als reales Bezugsobjekt der Erläuterungen zur Motivation von Landwirten in der Bewässerungswirtschaft und der Analyse von Performance Assessment als Managementinstrument der Kontrolle in der Bewässerung. Die Ergebnisse der Studie machen deutlich, dass die Landwirte ihren persönlichen Nutzen vor den Nutzen der Allgemeinheit stellen. Ihre Motivation zur Teilnahme an Betrieb und Unterhaltung der Bewässerungsinfrastruktur resultiert vorrangig aus dem erwarteten ökonomischen Nutzen für sich selbst. Die Autorin hat als Ergebnis ihrer Studie einige grundsätzliche Bedingungen und Ansatzpunkte für die Partizipation der Landwirte herausgearbeitet und Vorschläge für die Verbesserung des Performance Assessment gemacht. Sie weist aber auch auf das unterschwellig bestehende Konfliktpotential zwischen Administration und Wassernutzern hin. Reale Chancen der Konfliktbewältigung konnten allerdings nicht ausgemacht werden.

Peter Wolff, Witzenhausen

N. A. Wahl; 2003

Schätzung der Bodenwasserspeicherkapazität durch Simulation der genutzten Dornbuschsavanne in Namibia.

129 Seiten mit 20 Abbildungen und 15 Tabellen. Mitteilungen der Geographischen Gesellschaft in Hamburg, Band 94. Franz Steiner Verlag, Stuttgart. ISBN 3-515-08354-5 Kart. € 30.-

Die vorliegende Arbeit versucht, nach Angaben des Autors, einen Beitrag zum Problem der Abschätzung und Vorhersagbarbeit der nachhaltigen Produktivität der Dornbuschsavanne der trockenen Tropen Afrikas zu liefern. Dies sei auf der Grundlage von Klima, Nutzungsintensität und Standortverhältnissen sowie den Mengenanteilen der Komponenten der annuellen und perennen Gräser sowie der Gehölzpflanzen mit einem digitalen dynamischen Simulationsmodell (BOWA) zu leisten. Das Modell ermöglicht eine Schätzung der Bodenwasserspeicherkapazität (BSWK) sowie die flächenhafte Kartierung der Ergebnisse.

In der Arbeit werden zunächst die Problemstellung und das Ziel der durchgeführten Untersuchungen sowie der Stand der Forschung ausführlich und nachvollziehbar dargestellt. Es folgen die Darlegung des benutzten Materials und der angewandten Methoden, sowie eine Beschreibung des Untersuchungsgebietes. Nach Darstellung der erzielten Ergebnisse erfolgt die Diskussion. Im abschließenden Abschnitt „Fazit und Ausblick" zeigt der Autor die Anwendungsmöglichkeiten der vorgestellten Methode, vor allem auch deren derzeitige Grenzen auf. Dem Autor ist zuzustimmen, dass die Arbeit einen Beitrag zur Bereitstellung von Daten für die Vorhersage wichtiger quantitativer Eigenschaften der natürlichen Pflanzenformationen unter Weidebelastung leistet, wie sie z.B. in Klimamodellen zur Rückkoppelung an die Vegetationsdecke benötigt werden. Dies insbesondere da die Klimamodelle u.a. in diesem Bereich deutliche Defizite aufweisen. Eine Bedeutung für das praktische Weidemanagement kann der Arbeit derzeit wohl kaum zugesprochen werden. Ob damit z.B. eine Beurteilung der praxisrelevanten nachhaltigen Tragfähigkeit in semiariden Wirtschaftsräumen, die unter Weidebelastung stehen, möglich ist, erscheint fraglich.

Peter Wolff, Witzenhausen

G. H. J. Grubben and O. A. Denton (eds.); 2004

Plant Genetic Resources of Tropical Africa 2
Vegetables.

668 pages, ISBN 90-5782-147-8, Backhuys Publisher, Leiden, NL
PROTA Foundation, Wageningen, € 40 (Industrialised Countries) € 20 (Developing countries)

PROSEA (Plant Resources of South-East Asia) is well known among researchers on crop sciences. Now another project has started: PROTA (Plant Resources of Tropical Africa). Altogether 16 volumes are going to be prepared under the general editors R.H.M.J. Lemmens and L.P.A. Oyen. The editors of this volume are well known vegetable specialists from the Netherlands and Nigeria, respectively. Many more specialists have contributed (5 pages). After a short introduction (e.g. choice of species and needs one page for explanation), the vegetables (mostly primary use) are treated alphabetically. For each species (full citation of botanical name and protologue) the following topics are treated for important species: chromosome number, synonyms (in short form), vernacular names, origin and geographical distribution, uses, production and international trade, properties, description, other botanical information, growth and development, ecology, propagation and planting, management, diseases and pests, harvesting, yield, handling after harvest, genetic resources, breeding, prospects, major references, other references, sources of illustration and authors. An astonishing wealth of vegetables has been compiled. By comparison with Mansfeld's Encyclopedia (HANELT and IPC, 2001), the world dictionary of crop plants, the following new cultivated vegetables could be found:

- *Acanthophoenix rubra* (Bory) H. Wendl. (Palmae)
- *Amaranthus thunbergii* Moq. (Amaranthaceae).

- *Caralluma edulis* (Edgew.) Benth. ex Hook. f. (Asclepiadaceae).
- *Caylusea abyssinica* (Fresen.) Fisch. et C.A. Mey. (Resedaceae).
- *Commelina africana* L. (Commelinaceae).
- *Commiphora rostrata* Engl. (Burseraceae).
- *Corchorus tridens* L. (Malvaceae).
- *Crotalaria natalita* Meisn.(Leguminosae).
- *Cucumis africanus* L. f. (Cucurbitaceae).
- *Cyphostemma adenocaule* (Steud. Ex A. Rich.) Wild. et R.B. Drumm. (Vitaceae).
- *Dictyosperma album* (Bory) Scheff. (Palmae).
- *Gnetum africanum* Welw. (Gnetaceae).
- *Justicia ladanoides* Lam. (Acanthaceae).
- *Kedrostis pseudogijef* (Gilg) C. Jeffrey (Cucurbitaceae).
- *Leptatenia hastata* (Pers.) Decne. (Asclepiadaceae).
- *Marsilea minuta* L,. (Marsileaceae).
- *Melochia corchorifolia* L. (Malvaceae).
- *Micrococca mercurialis* (L.) Benth. (Euphorbiaceae).
- *Myrianthus arboreus* P. Beauv. (Urticaceae).
- *Ophioglossum reticulatum* L. (Ophioglossaceae).
- *Oxygonum sinuatum* (Meisn.) Dammer (Polygonaceae).
- *Solanum schumannianum* Dammer (Solanaceae).
- *Triumfetta annua* L. (Tiliaceae).

In addition, many weeds with a potential towards crop plants are mentioned. A separate list is devoted to vegetables with other primary use (7,5 pages). Finally, an extensive literature list (pp. 567 - 651), indices for scientific plant names (pp. 652 - 659) and vernacular plant names (pp. 660 - 666) as well as a short outlook for PROTA , are presented. The book with many plant drawings (several from PROSEA) and crop distibution maps for tropical Africa is an outstanding achievement for use and conservation of plant genetic resources.

References: P. Hanelt and Institute of Plant Genetics and Crop Plant Research (eds.), 2001: Mansfeld's Encyclopedia of Agricultural and Horticultural Crops. 6 vols., Springer, Berlin.

K. Hammer, Witzenhausen

C. de Haan (ed.); 2004

Veterinary institutions in the developing world: current status and future needs.

Scientific and Technical Review, Volume 23 (1),
World Organisation for Animal Health, Paris , 416pp., Format: 21 $\times$ 29.7 cm,
ISBN 92-9044-605-6, ISSN 0253-1933 , Price: 50€ (airmail postage is included for all countries), April 2004

This review analyses the physical, technical and organisation infrastructure of the animal health institutions mainly of the developing world and some from the developed world with the objective to understand the possibilities and limitations to secure animal health and the risk of diseases from animal origin. Discuses the model of private animal health service in comparison to public service.

In the section of country case study there is a chapter about the transition of animal health systems in countries of eastern Europe, many of them new members of the European union. Take into account the veterinary (professional) activities but also the para-veterinary and auxiliaries services for example the traditional livestock healers (para-professionals).

The governments of 160 countries are members of the world animal health organization OIE (Office International des epizooties). In 2001 it identifies the welfare of animals as a new issue for its attention in addition to its long-established status as the reference body on animal diseases and zoo noses.

There is a good source of information for epidemiologist with interest to develop animal health security.

Albert Sundrum; Wilbert Trejo-Lizama, Witzenhausen

Yacov Tsur, Terry Roe, Rashid Doukkale, Ariel Dinar; 2004

Pricing Irrigation Water. Principles and Cases from Developing Countries.

310 pages, 105 Tables, 24 Figures. Resources for the Future, Washington DC, USA, 2004. ISBN 1-891853-76-7 (hardcover: alk. Paper). Price: $ 65.00.

Apart from the four main authors nine scholars have contributed to this comprehensive assessment of water resources utility and pricing policy. A new framework is developed, based on farm level analysis of derived demand for irrigation water, pricing and its interaction with economic policies. Cases from Morocco, China, Mexico, South Africa and Turkey are presented. The assessment of guidelines on microeconomic level is analysed with respect to economy wide implications. Economic principles are developed which underlie demand and supply of irrigation water, its productive allocation and associated welfare concepts deriving from respective policies regarding water use and pricing.

In spite of worldwide scarcity of water resources, irrigation water as a decisive factor of production in agriculture is frequently undervalued which limits effective allocation according to marginal productivity. Changes in pricing policies, though often debated, are highly sensitive, and have to be linked to economic reforms on a higher level. Nevertheless, the cases of the five countries studied where irrigated agriculture contributes between 15 % and 27 % to Gross National Product, exemplify irrigation pricing policies which may serve as guidelines for developing countries under comparative conditions.

Eckhard Baum, Witzenhausen

Umweltbundesamt; 2004

Integration of Biodiversity Concerns into Climate Change Mitigation Activities

Der Praxisleitfaden „Integration of Biodiversity Concerns into Climate Change Mitigation Activities“ ist als Sonderpublikation des UBA kostenlos beim Zentralen Antwortdienst (ZAD), Postfach 33 00 22, 14191 Berlin oder über die E-Mail-Adresse info@umweltbundesamt.de, erhältlich.

Klima schützen und Biodiversität erhalten

UBA veröffentlicht Praxisleitfaden: Aspekte der Biodiversität bei Klimaschutzmaßnahmen berücksichtigen

Die vom Menschen zusätzlich in die Atmosphäre eingebrachten Treibhausgase - zum Beispiel aus Verkehr, Industrie und den Haushalten - führen zu weltweiten Klimaänderungen. Die internationale Umweltpolitik reagiert darauf mit Maßnahmen, die zwar das Klima schützen, dabei jedoch andere Schutzgüter - wie etwa die biologische Vielfalt (Biodiversität) - gefährden können. Das kann auch zum Rückgang der biologischen Vielfalt führen. Um solche Konflikte und später anfallende hohe Regenerationskosten zu vermeiden, hat das Umweltbundesamt (UBA) jetzt den Praxisleitfaden „Integration of Biodiversity Concerns into Climate Change Mitigation Activities“ veröffentlicht. Dieser hilft, Biodiversitätsaspekte rechtzeitig und umfassend bei der Maßnahmenplanung zu berücksichtigen.

Die prognostizierten Konsequenzen der Klimaänderungen für Mensch und Umwelt werden von Region zu Region unterschiedlich ausfallen. Beispielsweise wird es in einigen Gegenden voraussichtlich weniger, in anderen eher mehr Niederschläge geben. Die Temperaturen steigen an, die Zahl der Dürren und Hochwasserereignisse nehmen eher zu. Das verändert auch unsere natürlichen Lebensgrundlagen - die Vielfalt der Lebewesen genauso wie die Stoff- und Energiekreisläufe. Maßnahmen, die dieser Entwicklung entgegenwirken, sind dringend notwendig.

„Einige Projekte stellen eine ernste Gefahr für die biologische Vielfalt dar - zum Beispiel das Aufforsten mit schnellwachsenden gebietsfremden oder gentechnisch veränderten Baumarten oder der Aufstau natürlicher Gewässer zur Energienutzung“, so Prof. Dr. Andreas Troge, Präsident des UBA.

Vom Erhalt oder der Wiederherstellung der standorttypischen Biodiversität würde der Klimaschutz dagegen profitieren: Artenreiche, am natürlichen Standort regulär vorkommende Wälder speichern auf Dauer mehr Kohlenstoff. Sie sind gegenüber Störungen wesentlich stabiler. Bei Monokulturen kann ein Schädlingsbefall die gesamte Anpflanzung vernichten.

Intakte Ökosysteme erbringen wertvolle Dienstleistungen. Die biologische Vielfalt trägt durch das Speichern von Kohlenstoff und das Regulieren des Wasser- sowie des Energiehaushalts bedeutend zum Klimaschutz bei.

Die Hintergründe sind im Abschlussbericht des Projekts „Zusammenstellung und Auswertung geeigneter Kriterien, Indikatoren, UVP und dergleichen für die notwendige Berücksichtigung von Biodiversitätsaspekten bei Maßnahmen des Klimaschutzes, ins-

besondere zu Landnutzungsänderungen und im Energiesektor“ dargestellt und als Nr. 04/04 (deutsch) und 05/04 (englisch) der Reihe „Climate Change“ des UBA für jeweils 10 € erhältlich. Bestellungen sind ebenfalls über den ZAD möglich.

Presse-Information, UBA, Berlin

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 106, No. 1, 2005, page 94

Announcement
Deutscher Tropentag 2005

The Global Food & Product Chain-Dynamics, Innovations, Conflicts, Strategies
October 11 - 13, 2005, University of Hohenheim, Stuttgart

General information

The annual Conference on Tropical and Subtropical Agricultural and Natural Resource Management (DEUTSCHER TROPENTAG, DTT) is jointly organized by the universities of Berlin, Göttingen, Hohenheim, Bonn and Kassel-Witzenhausen as well as by the Council for Tropical and Subtropical Research (ATSAF e.V) in cooperation with BEAF/ GTZ.
DTT Deutscher Tropentag 2005 will be held in Stuttgart-Hohenheim. All students, Ph. D. students, scientists, extensionists, decision makers, politicians and practical farmers, interested and engaged in Agricultural Research and Rural Development in the Tropics and Subtropics are invited to participate and to contribute.

Target of the Conference

Meeting, exchange of knowledge and experience and interdisciplinary, scientific discussions on global challenges - to balance the production of sufficient, high quality food for an ever increasing world population and

- an improved livelihood, health and education of the rural population as well as reduced pressure on the environment caused by agricultural production.
- Information exchange on new approaches to optimize the utilization of scarce resources like soil, energy and water.

Plenary Session

Tomorrow's world should not be worse than today's! Sustainability can only be achieved by situation-conform traditional and/or new technologies in agriculture and thorough and efficient utilization of scarce resources but crucial is also the political, economic environment. Invited international speakers will present their views, policy, philosophy and recommendation.

Special Session

On the occasion of this conference a special plenary session will be devoted to the presentation of the

- "Hans H. Ruthenberg-Graduate-Award" and the
- "Josef G. Knoll-Science-Award"

by the "Vater and Sohn Eiselen Stiftung", Ulm

Further information under: http://www.tropentag.de
or Dr. Christian Hülsebusch, Dr. Eric Tielkes,
E-Mail: huelse@uni-hohenheim.de; tielkes@uni-hohenheim.de

Notes to authors

The Journal of Agriculture in the Tropics and Subtropics publishes papers and short communications dealing with original research in the fields of rural economy and farm management, plant production, soil science, animal nutrition and animal husbandry, veterinary hygiene and protection against epidemics, forestry and forest economy.
The sole responsibility for the contents rests with the author. The papers must not have been submitted elsewhere for publication. If accepted, they may not be published elsewhere without the permission of the editors.
Manuscripts are accepted in German, English, French, and Spanish. Papers may not be published in the order of receipt, those that require minor amendments, only are likely to appear earlier. Authors are advised to retain one copy of the manuscript themselves as the editors cannot accept any responsibility for damage or loss of manuscripts.

1. *Contents of the manuscripts*

Findings should be presented as brief as possible. Publication of a paper in consecutive parts will be considered in exceptional cases.
The following set-up is recommended:
The introduction should be as brief as possible and should concentrate on the main topics of the paper. Reference should be made to recent and important literature on the subject, only.
Materials used and methods applied should be explained briefly. Well-known or established methods and procedures should not be described. New or important methods should be explained. With all its brevity, this part should enable the reader to assess the findings adequately.
Tables and Figures should be used to effectively present the results. Explanations and other remarks on the results can be included in the text.
Discussion of results should also refer to relevant literature on the topic and lead to clear conclusions. Recommendations with respect to further research needed on the respective subject will increase the value of the paper.
The summary should concentrate on the main results and conclusions to highlight the author's contribution. It should be suitable for information storage and retrieval.

2. *Form of the manuscripts*

Manuscripts should be typed double-spaced with a wide margin, preferable on disk.
The documents should be prepared with standard software (Microsoft Word, Word Perfect, LaTeX). Alternatively, the manuscript can be submitted as a simple text/rtf file together with a printed version of the original format.
Please do not use automated or manual hyphenation.
Title, headings and references (names of authors) should not be in capitals.

Tables and figures should be attached at the end of the document or separately.
The preferred position for the insertion of tables and figures should be marked on the margin of the text.

The manuscript should not be longer than 15 typed pages including tables, figures and references.
The title of the paper is followed by the name(s) and address(es) of the author(s).
The abstract should be followed by a list of keywords (up to eight).
For each paper, a summary must be submitted in the same language (not more than 20 lines) and in English, if the paper is written in an other language.

Tables should not be prepared with blanks and should fit on a DIN A5 page
(max. width: 12cm (landscape: 18.5cm) with a minimum font-size of 7pt.).
All tables should have captions and should be numbered consecutively.

Figures should be black&white/greyscaled and suitable for reproduction (if possible, in postscript vector format, .ps .eps). Photos should be high-gloss prints of good contrast, maximum size 13 by 18 cm, line drawings with Chinese ink on white or transparent paper. All figures should be numbered consecutively. A separate list of captions for illustrations has to be added.

S.I. (System International) units have to be used throughout.
References in the text should be made by the name of the author and the year.
Each paper should have an alphabetical list of references giving name and abbreviated first name of the author(s), title of the paper, name of the journal, number of the volume, year, page numbers; for books: title, place of publication, and year.
On publication, each author will receive two copy of the Journal

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April 2004