Journal of Agriculture and Rural Development in the Tropics and Subtropics

DITSL

Vol. 107 No. 1 2006

kassel university press

Journal of Agriculture
and Rural Development in
the Tropics and Subtropics

Volume 107, No. 1, 2006

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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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 107, No. 1, 2006, pages 1–10

Assessing Production Efficiency of Dairy Farms in Burdur Province, Turkey

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Abstract

This study finds that a sample of 132 dairy farmers located in Burdur Province, Turkey, are producing at a low level of production efficiency. Efficiency ranges from 24 percent to 94 percent, with the average being 50 percent. Eighty one percent of the variation in output among the sampled farmers is due to differences in their production efficiency. If a farmer with average efficiency improved efficiency to that of the most efficient farmer in the sample, then the average dairy farmer could realize a 47 percent saving in cost. Two statistically significant factors associated with the variation in production efficiency are identified: the type of feeding system used and herd size. Use of extension programs explained little of the variation in production efficiency.

Keywords: stochastic frontier analysis, production efficiency, dairy farms

1 Introduction

Turkey's dairy sector historically has been one of its most important farm sectors both in terms of value added and employment. However, since 1990, milk production in Turkey has decreased from 9.6 million tons per year to 8.2 million tons/year, a decline of 15.3 percent (FAO, 2003). Over the same period, number of dairy cows has decreased from 5.9 million in 1990 to 4.2 million in 2003, or by 29 percent.

To help its dairy sector cope with its decline, Turkey has adopted various public policies. They include a milk premium, a livestock headage payment and roughage feed support program. Because Turkey is seeking admission to the European Union, these policies have come under review as Turkey aligns its agricultural policy with EU agricultural policy. In addition, World Trade Organization rules require countries to reduce their trade barriers, including their custom level. These policy changes are likely to exacerbate the economic pressures that have developed in Turkey's dairy industry over the last quarter century.

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A key to improving the competitiveness of Turkey's dairy industry is to improve its economic efficiency. Numerous studies have examined dairy production efficiency in both developed and developing countries. Recent studies include MBAGA *et al.* (2003) and SHARMA and GULATI (2003). However, to the authors' knowledge, no study has examined the production efficiency of dairy farms in Turkey. The objective of this study is to analyze the production efficiency of dairy farms in Burdur Province, Turkey and to determine farm specific factors that are associated with the variation in efficiency among dairy farmers.

2 Material

The data used in this study were collected through personal interviews with dairy farmers in Burdur Province, Turkey, during the Spring of 2004. This area was selected because milk production and processing are important activities. Forty six percent of farm income comes from the dairy sector in Burdur Province, which is much higher than the 32 percent average for Turkey (SIS, 2003).

A two stage sampling process was used. In the first stage, 18 villages in Burdur, Bucak and Yesilova Counties were identified through communication with the Directory of Agriculture in Burdur Province. According to farms records of the Directory of Agriculture, 80 percent of the dairy cows in Burdur Province are located in these counties. The farmers in the 18 villages formed the population for this study.

In the second stage, 138 farmers from the 18 villages were chosen for interviews using a stratified random sampling procedure. The sample was stratified by herd size. Useable interviews were obtained for 132 farms, which form the data set for this study. The sampling parameters are presented in Table 1.

Table 1: Sampling Parameters of Dairy Producers, Burdur, Bucak and Yesilova Counties, Burdur Province, Turkey, 2004.

Herd Size (cows)	*Farmer population*	*Farmers sampled**	*Distribution of sampled farmers*
1-5	1022	54	41 %
6-10	640	43	33 %
11+	554	35	26 %
Total	2216	132	100 %

* These are farmers with useable interviews. The original sample included 138 dairy farmers.

A wide range of socio-economic and business characteristics were elicited in the interview. They included number of cows, amount of milk produced, major dairy inputs (feed, labor, capital, and cultivated land), hectares of fodder crops, operator's education and age, farm contact with extension, and membership in cooperative and producer organizations.

Descriptive statistics of the variables are presented in Table 2. The dairy herds ranged from 1 to 48 cows. The average was 10 cows. Input use varied substantially, with the maximum use being at least 11 times the minimum use for each of the four major input categories.

Table 2: Characteristics of Surveyed Dairy Producers, Burdur, Bucak and Yesilova Counties, Burdur Province, Turkey, 2004.

Variable	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Herd Size (number)	10	9	1	48
Annual Milk Production (kg/cow)	2111	899	340	6750
Concentrate Feed (kg/herd)	1570	574	225	4500
Roughage Feed * (kg/herd)	1796	1130	2	6525
Human Labor (Man-days/herd)	30	17	6	91
Farm Capital (New Turkish Lira/herd)	4019	2414	1610	18100
Fodder Crop (ha)	2.6	2.4	0	14.1
Education Attainment (years)	6	2	0	15
Age (years)	48.5	13.5	23	75
Use Individual Feeding System (%)	62			
Contact with Extension (%)	66			
Cooperative Member (%)	100			

* Roughage feed equals the consumption of succulent roughage plus dry roughage, assuming a dry matter content of 30 % and 90 % respectively.

3 Methods

Farrell (1957) developed the first theoretical treatment of production technical efficiency (hereafter, referred to as production efficiency). The standard methodology for measuring farm level production efficiency is to estimate a production frontier that envelopes all the input/output data available for the analysis. Within this context, technical efficiency of a farm is measured relative to the input/output performance of all other farms in the sample. Farms located on the production frontier are considered efficient. Farms located inside the frontier are considered inefficient because the farm is generating less output that is feasible given its level of inputs.

A Cobb-Douglas production function is used to estimate the stochastic production frontier (SPF)[4]. This function has been widely used to analyze production efficiency in developing and developed countries (Bravo-Ureta and Rieger, 1991; Sharma *et al.*,

[4] In preliminary analyses, the Cobb-Douglas model was found to adequately represent the data, given the specification of a translog stochastic frontier involving the four input variables.

1999; BINAM *et al.*, 2004). TAYLOR *et al.* (1986) argued that, despite its well-known limitations, the Cobb-Douglas function provides an adequate representation of production technology as long as the analysis is interested in the efficiency of production and not the structure of the production technology.

Given the choice of the Cobb-Douglas production function, the data available from the survey, and the objective of explaining the variation in production efficiency among the sampled dairy farms, the following SPF model was estimated[5]:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{4} \beta_j \ln X_{ji} + v_i - u_i \tag{1}$$

and

$$u_i = \delta_0 + \sum_{m=1}^{6} \delta_m Z_{mi} \tag{2}$$

where, $\ln$ denotes natural logrithm; Y_i is annual milk production of farm i measured in kilograms; X_{1i} is annual consumption of purchased dairy concentrate in tons; X_{2i} is annual consumption of roughage feed in tons (equals consumption of succulent roughage plus dry roughage, assuming a dry matter content of 30 % and 90 % respectively (BRAVO-URETA and RIEGER, 1991); X_{3i} is human labor in man-days; X_{4i} is total farm capital defined by opportunity cost of total value of assets in New Turkish Lira (TL), and Z_{mi} are socio-economic charecteristics. v_i is a symmetric, identically and independently distributed $N(0, \sigma_v^2)$ error term. It represents random variation in production due to random exogenous factors, such as measurement errors, unobserved production inputs, and statistical noise. u_i is a non-negative error term. It reflects technical inefficiency relative to the stochastic frontier.

The socio-economic characteristics (Z_{mi}) examined in this study were defined as follows. Z_{1i} is farmer age. Z_{2i} is a binary variable equal to one if the farmer had a degree higher than elementary school and to zero otherwise. Z_{3i} is a binary variable equal to one if the farmer used an individual feeding system and to zero otherwise. Z_{4i} is a binary variable equal to one if the farmer contacted an extension officer in the past year and to zero otherwise. Z_{5i} is total number of cows in the herd. Z_{6i} is number of hectares planted to fodder crops. Because all of the sampled farmers were members of the Agricultural Sale Cooperatives, this variable was not included in the regression equation.

Following COELLI and PERELMAN (1996), technical efficiency of farm i equal:

$$EEF_i = E\left[\exp(-u_i)|\varepsilon_i\right] = E\left[\exp\left(-\delta_0 - \sum_{m=1}^{5} \delta_m Z_{mi}\right)|\varepsilon_i\right] \tag{3}$$

where E is the expectation operator. The technical inefficiency of farm i, i.e. u_i, is conditional upon the observed value of ε from the estimated Cobb-Douglas stochastic production frontier.

[5] For more detail on the SPF model, see BATTESE and COELLI (1995) and RAHMAN (2003)

Maximum likelihood is used to estimate simultaneously the unknown parameters of the Cobb-Douglas stochastic frontier (Equation 1) and the measure of inefficiency (Equation 2). The likelihood function is expressed in terms of the variance parameters, $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \frac{\sigma_u^2}{\sigma^2}$ (BATTESE and COELLI, 1995). γ must lie between zero and one. Zero indicates that the deviation from production efficiency is due entirely to noise; one indicates that the deviation is due entirely to the farmer's production inefficiency (BATTESE and COELLI, 1995). FRONTIER 4.1 (COELLI, 1996) is used to obtain the maximum likelihood estimates (MLE).

4 Results and Discussion

The estimated Cobb-Douglas production function is presented in Table 3. As expected, the production inputs have a positive coefficient, implying that the amount of milk produced increases as the use of these inputs increase. Except for forage feeds, the coefficients are significant at least at the 95 percent level of statistical confidence.

Table 3: Maximum-likelihood estimates of profit frontier function of dairy farmers, Burdur, Bucak and Yeşilova Counties, Burdur Province, Turkey, 2004.

Variable	*Parameters*	*Coefficients*	*t-ratio*
Constant	β_0	2.03	1.00
$\ln(concentratefeed)$	β_1	0.284*	4.11
$\ln(foragefeed)$	β_2	0.06	1.54
$\ln(labor)$	β_2	0.15*	2.64
$\ln(capital)$	β_3	0.39**	2.54
Variance parameters			
$\sigma^2 = \sigma_v^2 + \sigma_u^2$		0.12	5.82
$\gamma = \frac{\sigma_u^2}{\sigma^2}$		0.89*	6.08
Log likelihood		-0.37	
LR statistic		14.56	

*,** significant at the 1 and 10% level respectively

To test for efficiency, the following base calculations were made: $\sigma^2 = \sigma_v^2 + \sigma_u^2 = 0.115$ and $\gamma = \frac{\sigma_u^2}{\sigma^2} = 0.89$. The null hypothesis that $\gamma = 0$ is rejected at the 99% level of statistical confidence (LR test statistics is 14.56), indicating that technical inefficiency effect exists. A γ^* of 0.81 indicates that 81 percent of the variation in output among the dairy farmers is due to differences in production efficiency[6].

Table 4 presents the distribution of production efficiency scores. Only two percent of the 132 sampled dairy farms had a production efficiency score that meant the farm was operating at 90 percent or more of their potential production efficiency based on the estimated production efficiency frontier. The highest score was 94 percent. The lowest score was 24 percent, and the average score was 50 percent. Fifty-nine percent of the sampled dairy farms were operating at less than 50 percent efficiency. When taken as a group, these scores suggest considerable potential for improving production efficiency by increasing output and/or reducing inputs. For example, if a farmer with average efficiency increased the farm's efficiency to that of the most efficient farm in the sample, this average dairy farmer could realize a 47 percent (i.e., 1- (50/94) saving in costs.

Table 4: Distribution and summary statistics for production efficiency scores of dairy farmers in Burdur, Bucak and Yesilova Counties, Burdur Province, Turkey, 2004.

Production Efficiency Score (%)	*Number of Dairy Farms*	*Percent of Dairy Farms*
$>$90.0	2	2
$>$80.0 $\leq$90	8	6
$>$70.0 $\leq$80	7	5
$>$60.0 $\leq$70	15	11
$>$50.0 $\leq$60	23	17
$>$40.0 $\leq$50	35	27
$>$30.0 $\leq$40	28	21
$>$20.0 $\leq$30	14	11
Less Than 20	0	0
Mean	50	
Minimum	24	
Maximum	94	

Previous studies of the production efficiency of dairy farms have found that on average production efficiency was 83 percent for a sample of U.S. (New England) dairy farms (Bravo-Ureta and Rieger, 1991), 92 percent to 95 percent depending on type of production function specified for a sample of Canadian (Quebec) dairy farmers (Mbaga *et al.*, 2003), 77 percent for a sample of Ecuadorian dairy farms (Bailey *et al.*, 1989), 79 percent and 84 percent for a sample of dairy farmers in the Northern and Western

[6] γ does not equal the ratio of the variance of inefficeincy to total residual variance. The reason is that the variance of u_i equals $\left(\frac{\pi-2}{\pi}\right)\sigma^2$, not σ^2. Thus, the relative contribution of inefficiency to total variance γ^* equals $\frac{\gamma}{\left(\frac{\gamma+(1-\gamma)\pi}{\pi-2}\right)}$ (Rahman, 2003).

regions of India, respectively (Sharma and Gulati, 2003). This comparison does not mean that this sample of Turkish dairy producers is less efficient than these dairy farmers in other countries. The reason is that the production frontier may differ among each country. This comparison only means that, relative to their production frontier, the sample of Turkish dairy farmers Burdur province did not operate as close to their production frontier as did the producers in the other studies.

Table 5 contains the results for the regression analysis of the factors associated with the variation in production efficiency among the sampled farms. The dependent variable is the degree of production efficiency (see equation 3). Because of the way that equation 3 is written, a variable with negative sign means that it is positively related to the efficiency of the farm.

Table 5: Maximum-likelihood estimates of variables associated with production efficiency of dairy farmers, Burdur, Bucak and Yeşilova Counties, Burdur Province, Turkey, 2004.

Variable	*Parameter*	*Coefficient*	*t-ratio*
Constant	δ_0	0.893	2.40
Age	δ_1	-0.032	-0.85
Education	δ_2	-0.043	-0.59
Feeding Type	δ_3	-0.164*	-2.12
Contact with Extension	δ_4	-0.050	-0.68
Total Herd Size	δ_5	-0.067*	-1.80
Forage Feed land	δ_6	0.002	1.10

* significant at the 5 % level

This study finds that age is positively related with production efficiency but is statistically insignificant at the 90 percent level of statistical confidence. This finding is in line with the expected *a priori* indeterminate relationship. Older farmers have acquired more human capital through their experiences, but they also may be less willing to adopt new ideas. Consistent with this *a priori* expectation, findings from empirical previous studies are mixed. For example, Abdulai and Huffman (1998) find that older rice farmers in Northern Ghana were less efficient than younger farmers while Coelli *et al.* (2002) find that younger rice farmers in Bangladesh were more efficient than older rice farmers. Binici *et al.* (2006) found that age has no statistically significant effect on the technical efficiency of cotton farms in Turkey.

Education is positively associated with efficiency, but it is statistically insignificant. Similar results were reported for farmers in Bangladesh (Rahman, 2003), Ethiopia (Weier, 1999), and Cameroon (Binam *et al.*, 2004). Conceptually, education improves the skill and entrepreneurial ability of the farmer to organize inputs for maximum efficiency. However, JOSHI (1998) argues that the gains from education are higher in modernized agriculture than in traditional agriculture. The findings in this study are consistent with Joshi's argument.

Contact with an extension officer during the past year was positively related to efficiency but statistically insignificant. This finding is consistent with the findings of FEEDER *et al.* (2004); BINAM *et al.* (2004); RAHMAN (2003). Each of these studies involved farmers in developing countries. The inability to find statistical significance has been attributed to bureaucratic inefficiency, poor program design, (FEEDER *et al.*, 2004; BINAM *et al.*, 2004) and the use of a "top-down" instead of participatory approach (BRAUN *et al.*, 2002). Turkey's extension program has been characterized by a top-down approach (AKTAŞ, 2004). Thus, the lack of a participatory approach may explain the insignificance of Turkey's extension program in terms of its impact on the efficiency of these Turkish dairy farms.

The number of hectares of fodder crops is statistically insignificant and does not have the expected sign. Farmers who harvest larger acreages of fodder crops may use too much roughage in their feed rations because it is available. Proper nutritional balance between feed concentrates and roughage feed is widely recognized as a key to attaining production efficiency (BAILEY *et al.*, 1989).

In the study area, two types of feeding systems are used. In one system, the cows are fed individually. In the other system, the cows are fed as a group. Use of an individual feeding system was associated with a greater degree of efficiency. This relationship was significant at the 95 percent level of statistical confidence. One reason that an individual feeding system is more efficient is that the farmer can feed each cow a ration tailored to her production potential. In a group feeding system, the highest producing cows may not produce to their potential because they may not necessarily eat the right amount of feed.

Farm size had a positive relationship with dairy farm efficiency. This relationship was significant at the 95 percent level of statistical confidence. It is consistent with previous studies (BRAVO-URETA and RIEGER, 1991; TAUER, 2001) and with the expected existence of economies of size from economic theory.

5 Conclusion and Policy Implications

Stochastic Production Frontier analysis is used to analyze the production efficiency of a sample of 132 dairy farmers located in Burdur Province, Turkey. These farms have an average efficiency score of 50 percent. Further analysis reveals that 81 percent of the variation in output among the sampled farmers is due to differences in their production efficiency. These findings imply that the average dairy farmer in this sample has the potential to substantially increase their efficiency without changing their production frontier. Operating at a high efficiency relative to the production frontier is an important factor in remaining competitive and thus in business over time.

The analysis identified two statistically significant factors associated with the variation in production efficiency: individual instead of group feeding of cows, and larger herd size. Both factors are potentially attainable, although both have implementation costs. In particular, policy makers either must allow market forces to reward the formation of larger dairy farms or they must implement policies that help small dairy producers adjust by either getting larger, or by developing niche markets, or by exiting dairy farming, including the potential use of public funds to pay an exit bonus.

Individual feeding of cows could become the centerpiece of a national education campaign to improve dairy herd production efficiency. However, this study finds no statistically significant relationship between contact with extension and the degree of farm production efficiency. Thus, the success of a national education campaign to raise awareness of the value of individual dairy feeding systems may require a revamping of Turkey's extension program. If this option is deemed infeasible by policy makers, an alternative approach may be to create a separate program using other delivery mechanisms.

Acknowledgement
We are grateful to Suleyman Demirel University that has funded this research, No: 0906-M-04.

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Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 107, No. 1, 2006, pages 11–18

A Profitability Analysis of Investment of Peach and Apple Growing in Turkey

M. Uzunöz[*1] and **Y. Akçay**[2]

Abstract

This study was conducted to determine profitability and feasibility of fruit farms by investment analysis in Tokat - Turkey. The criteria of Net Present Value (NPV), Cost-Benefit Ratio (CBR) and Internal Rate of Return (IRR) were used for investment analysis. Three different discount rates (10%, 8% and 5%) were used to get the NPV and CBR for peach and apple. The NPV for peach were found to be positive (1113.6 $/da; 1454.7 $/da; and 2156.2 $/da). Also the NPV for apple were found to be positive (574.2 $/da; 805.4 $/da; and 1342.9 $/da). In addition to that, the CBR for peach were bigger than 1 (1.38; 1.43 and 1.51) and the CBR for apple were bigger than 1 (1.23; 1.27 and 1.33). The IRR for peach was 25.05 percent and 22.12 for apple. According to the results that were achieved by the study, it could be conducted that the investment is economically feasible. In the light of the findings of the present study, it can be perceived that the fruit farming can be one of the most important income sources for the farmers growing fruit in the research region in Turkey.

Keywords: fruit, internal rate of return, investment analysis, net present value, sensitivity analysis

1 Introduction

Turkey lies in the 36-42°north latitude and 26-45°east longitude and possesses a wide rage of climatic conditions from mild Mediterranean to cold continental that enable the cultivation of more than 75 crop species. Peach and apple can be grown in various regions of Turkey (HAKAN, 2003; SPO, 2001; ENGINDENIZ *et al.*, 2004). They are widely grown in Tokat province in Middle Blacksea Region and cover 28,1 percent of total planted fruit area.

An orchard is a long-term including establishment and maturity period investment and careful planning is essential to ensure economic success (MARINI, 1997). The producer would like to know the results of his economic activity by working out a detailed cost-benefit analysis of the investment in the project. Although the technical aspects of fruit production have been studied extensively, quantitative studies related to the economics

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of such farms are limited in literature. Therefore there is still a need for further study; especially at the local level. The main objective of the study is to analyze the feasibility and profitability of investment in fruit farms.

2 Materials and Methods

In the study, the data were obtained from the annual cost table prepared by the Research Institute of Rural Services in the region for the year of 2003. The economic life of the activity is taken as 20 years for peach and 30 years for apple. Establishment period for peach and apple are 5 and 7 years respectively. The profit was calculated and compared with real interest rate to find opportunity costs of enterprise.

Investment in an orchard will generate income and expenses for many years into the future. Discounting these future streams of money is the recommended analytical technique that determines the Net Present Value (NPV) in today's money. By comparing the NPV of each investment, the most profitable investment over time can be determined by selecting that investment with the highest NPV (Kelsey and Schwallier, 1999). In other words the NPV is the total present value of future revenues and costs of an activity (Castle *et al.*, 1987) and among the measures of investment returns over time, NPV offers the better measure of project worth (Swinton *et al.*, 1997). The consensus in the investment literature is that if the objective of a firm is the maximization of profit or wealth of a business, then the NPV model is the appropriate procedure to evaluate investment decisions (Tauer, 2002). The NPV was calculated by the formula $NPV = \frac{FV}{(1+i)^n}$ (Bechtel *et al.*, 1995) where FV is the future value of money, i is the interest or discount rate, and n is the number of years.

The CBR is the ratio obtained when the present worth of the benefit stream is divided by the present worth of the cost stream (Gittinger, 1982) and can be obtained as follows (Erkus and Rehber, 1998):

$$CBR = \frac{\sum_{t=0}^{n} R_t/q^t}{\sum_{t=0}^{n} C_t/q^t} \quad (1)$$

where R is the total revenue, C is the total cost, i is interest rate, and n is the number of years and $q^t = (1+i)^t$. If $CBR > 1$, then the total revenue is greater than the total cost, If $CBR = 1$ then the total revenue is equal to the total cost, and if $CBR < 1$ then the revenue is less than the total cost.

The internal rate of return (IRR) is a useful measure of project worth (Gittinger, 1982) and helps to determine the relative profitability of an investment (Bechtel *et al.*, 1995). IRR is discounted rate, which makes Net Cash Flows of the economic life of project zero (Tauer, 2000). The IRR formula is as follows:

$$IRR = r_1 + \frac{ND_1}{ND1 + ND_2}(r_1 - r_2) \quad (2)$$

where r_1 is the last discount rate which makes NPV positive, r_2 is the first discount rate which makes NPV negative, ND_1 is the last positive NPV, ND_2 is the first negative absolute value of NPV.

Sensitivity analysis is described as a technique for measuring the impact on project, while changing one or key input values about which there is uncertainty (Marshall, 1999).

Table 1: The investment cost of the farms ($/da)

Items	*Peach – year of establishment of production*				
	1	*2*	*3*	*4*	*5*
Soil preparing and planting	74.1	—	—	—	—
Maintenance	15.5	75.8	48.4	70.2	52.7
Harvesting-Transporting	—	—	2.8	10.0	13.0
Various inputs *	221.9	33.6	18.5	33.1	21.4
Other expenses (5%) †	15.6	5.4	3.5	5.7	4.3
Total variable costs	327.1	114.8	73.2	119.0	91.5
Capital interest (10%) ‡	32.7	11.5	7.3	11.9	9.2
Land Rent	82.5	82.5	82.5	82.5	82.5
Management cost (3%) §	9.8	3.5	2.2	3.6	2.7
Total fixed costs	125.0	97.5	92.0	98.0	94.3
Total	452.1	212.3	165.2	217.0	185.8

Items	*Apple – year of establishment of production*						
	1	*2*	*3*	*4*	*5*	*6*	*7*
Soil preparing and planting	25.5	1.1	1.1	1.1	1.1	1.1	1.3
Maintenance	9.4	22.6	27.4	20.5	37.5	38.1	45.0
Harvesting-Transporting	142.6	17.0	14.0	16.9	19.8	19.8	14.7
Various inputs *	—	—	—	—	—	—	22.7
Other expenses (5%) †	8.8	2.1	2.1	2.0	2.9	2.9	4.2
Total variable costs	186.3	42.8	44.6	40.5	61.3	61.9	88.0
Capital interest (10%) ‡	18.6	4.3	4.5	4.0	6.1	6.2	8.8
Land Rent	5.6	1.3	1.3	1.2	1.9	1.8	2.6
Management cost (3%) §	82.6	82.6	82.6	82.6	82.6	82.6	82.6
Total fixed costs	106.8	88.1	88.4	87.8	90.6	90.6	94.0
Total	293.1	130.9	133.0	128.3	151.9	152.5	182.0

* Cover pesticide, fertilizer, irrigation and labor costs
† The unexpected costs (transaction cost, transportation cost, labor and etc.), which occur during establishment period (Çiçek *et al.*, 2001).
‡ The interest rate of capital is 10 percent of total fixed establishment (Akçay *et al.*, 2004).
§ Management cost is taken as 3 percent of total establishment cost (Akçay and Uzunöz, 1999).

3 Results and Discussion

Establishment cost is an investment that takes time to pay off (Sharp and Cooley, 2004). The establishment costs of peach and apple production are given in Table 1.

As it can be seen from Table 2, the variable costs have a share of 65.0 percent for peach and 61.7 percent for apple in total production cost. With a 37.0 percent, maintenance has the biggest share for peach and with a 23.0 percent, various inputs for apple in the variable costs.

As it can be seen from Table 3, the annual revenue of the producer is coming from the principal product and intermediary income.

Table 2: The production costs ($/da).

Items	*Peach (year 6-20)*		*Apple (year 8-30)*	
	($/da)	*(%)*	*($/da)*	*(%)*
Variable costs				
Maintenance	133.4	37.0	45.1	15.0
Harvesting-Transporting	41.3	11.4	62.2	20.8
Various inputs	48.7	13.5	68.9	23.0
Other expenses (5%)	11.2	3.1	8.8	2.9
Total Variable Costs (1)	234.6	65.0	185.0	61.7
Fixed costs				
Capital interest (10%)	23.5	6.5	18.5	6.2
Management (3%) (*)	20.3	5.6	13.6	4.6
Land rent	82.5	22.9	82.5	27.5
Total Fixed Costs (2)	126.3	35.0	114.6	38.3
Total Production Costs (1+2)	360.9	100.0	299.6	100.0

* Management cost is 3% of gross production value.

Table 3: Income in the farms ($/da)

Income particulars	*Peach – year of production*					
	1	*2*	*3*	*4*	*5*	*year 6-20*
Principal product income	—	—	63.8	164.5	215.3	675.8
Intermediary income	123.3	23.7	98.4	—	—	—
Total	123.3	23.7	162.2	164.5	215.3	675.8

Income particulars	*Apple – year of production*							
	1	*2*	*3*	*4*	*5*	*6*	*7*	*year 8-30*
Principal product income	—	—	—	—	—	—	86.2	452.1
Intermediary income	206.1	23.7	123.3	164.5	23.7	215.3	37.2	—
Total	206.1	23.7	123.3	164.5	23.7	215.3	223.4	452.1

The Net Cash Flows are given in Table 4.

Table 4: Cash flows in the farms ($/da)

Income particulars	*Peach – year of production*					
	1	*2*	*3*	*4*	*5*	*6-20*
Annual Farm Income						
- Principal product income	—	—	63.8	164.5	215.3	675.8
- Intermediary income	123.3	23.7	98.4	—	—	—
Total Farm Income	123.3	23.7	162.2	164.5	215.3	675.8
Annual Costs						
- Investment costs	452.1	212.3	165.2	217.0	185.8	—
- Production costs	—	—	—	—	—	360.9
Total Operation Costs	452.1	212.3	165.2	217.0	185.8	360.9
Cash Flows	-328.8	-188.6	-3.0	-52.5	29.5	314.9

Income particulars	*Apple – year of production*							
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8-30*
Annual Farm Income								
- Principal product income	—	—	—	164.5	—	—	86.2	452.1
- Intermediary income	206.1	23.7	215.3	37.2	—			
Total Farm Income	206.1	23.7	123.3	164.5	23.7	215.3	223.4	452.1
Annual Costs								
- Investment costs	293.1	130.9	133.0	128.3	151.9	152.5	182.0	—
- Production costs	—	—	—	—	—	—	—	299.6
Total Operation Costs	452.1	212.3	165.2	217.0	151.9	152.5	182.0	299.6
Cash Flows	-87.0	-107.2	-9.7	36.2	-128.2	62.8	41.4	152.5

The annual profits (cash flows) were calculated by subtracting the annual costs from annual revenue for a period of 20 years for peach and 30 years for apple (Table 4).

The establishment year is taken as a base and from the following year to the end of economic life was taken as production period. The choice of discount rate is determined by the investor's assumptions about inflation, risk and earning potential of other investments. If a producer is financing the investment internally, then the loan rate would be replaced by the producer's opportunity cost in the computation. Therefore different discount rates (10, 8 and 5%) were used in the study. NPV of the period was calculated and given in Table 5.

The NPV achieved for each discount rates are 1113.6 $/da; 1454.7 $/da; and 2156.2 $/da, for peach respectively. The NPV achieved for each discount rates are 574.2 $/da; 805.4 $/da; and 1342.9 $/da, for apple respectively.

Table 5: Cost–Benefit Ratio according to 10, 8 and 5 % discount rates.

	Peach										
			Discount rate 10%			Discount rate 8%			Discount rate 5%		
Year	*Incomes ($/da)*	*Costs ($/da)*	*Discount*	*Disc. Income ($/da)*	*Disc. Costs ($/da)*	*Discount*	*Disc. Income ($/da)*	*Disc. Costs ($/da)*	*Discount*	*Disc. Income ($/da)*	*Disc. Costs ($/da)*
1	123.3	452.1	1	123.3	452.1	1	123.3	452.1	1	123.3	452.1
2	23.7	212.3	0.909	21.6	193.0	0.926	22.0	196.6	0.952	22.6	202.2
3	162.2	165.2	0.826	134.0	136.5	0.857	139.0	141.6	0.907	147.1	149.9
4	164.5	217.0	0.751	123.6	163.0	0.794	130.6	172.3	0.864	142.1	187.5
5	215.3	185.8	0.683	147.1	126.9	0.735	158.2	136.6	0.823	177.1	152.9
6-20	675.8	360.9	5.195	3510.7	1875.2	6.292	4251.7	2270.9	8.539	5770.8	3082.2
Total				4060.3	2946.7		4824.8	3370.1		6383.0	4226.8
NPV					1113.6			1454.7			2156.2
B/C					1.38			1.43			1.51
IRR						25.05					

	Apple										
			Discount rate 10%			Discount rate 8%			Discount rate 5%		
Year	*Incomes ($/da)*	*Costs ($/da)*	*Discount*	*Disc. Income ($/da)*	*Disc. Costs ($/da)*	*Discount*	*Disc. Income ($/da)*	*Disc. Costs ($/da)*	*Discount*	*Disc. Income ($/da)*	*Disc. Costs ($/da)*
1	206.1	293.1	1	206.1	293.1	1	206.1	293.1	1	206.1	293.1
2	23.7	130.9	0.909	21.6	119.0	0.926	21.9	121.2	0.952	22.6	124.7
3	123.3	133.0	0.826	101.9	109.9	0.857	105.7	114.0	0.907	111.8	120.6
4	164.5	128.3	0.751	123.6	96.4	0.794	130.6	101.8	0.864	142.1	110.8
5	23.7	151.9	0.683	16.2	103.8	0.735	17.4	111.7	0.823	19.5	125.0
6	215.3	152.5	0.621	133.7	94.7	0.681	146.5	103.8	0.784	168.7	119.5
7	223.4	182	0.564	126.1	102.7	0.630	140.8	114.7	0.746	166.7	135.8
8-30	452.1	299.6	5.014	2266.9	1502.3	6.536	2954.7	1958.0	10.065	4550.5	3015.6
Total				2996.1	2421.9		3723.7	2918.3		5388.0	4045.1
NPV					574.2			805.4			1342.9
B/C					1.23			1.27			1.33
IRR						22.12					

CBR is calculated by dividing the total discounted incomes by the total discounted costs. The CBR in all the three discount rates is greater than 1 for peach and apple (Table 5). This means that the producer has a positive return in the production of peach and apple.

Internal rates of return (IRR) are given in Table 5. IRR was found as 25.05 percent for peach and 22.12 percent for apple, which are greater than the interest rate of capital. This means that the farmers were making more than two times of capital interest in the peach and apple production. Also the IRR was more than two times IRR (10.78%) AKÇAY and UZUNÖZ (2005) found for peach in Amasya in Middle Blacksea Region.

In the sensitivity analysis, three different NPV, CBR and IRR were found under the three different assumptions. When a 10 percent total cost overrun and 10 percent reduction of product price were assumed (Table 6), the IRR's for peach decreased from

25.05 percent to 22.70 and 20.21 percent, respectively and the IRR's for apple decreased from 22.12 percent to 16.25 and 15.57 percent, respectively. The results showed that the IRR's for peach and apple are greater than the interest rate of capital.

In the light of the findings determined from the present study, it can be concluded that peach and apple farming can be one of the most important income sources for the fruit farmers of rural provinces of Tokat-Turkey.

Table 6: Sensitivity Analysis

	Peach		
	Assuming 10 percent higher total cost		
Discounted Rate (%)	10	8	5
NPV ($)	819.3	1118.2	1735.0
CBR	1.25	1.30	1.37
IRR (%)		20.70	
	Assuming 10 percent lower price of product		
Discounted Rate (%)	10	8	5
NPV ($)	707.9	972.7	1518.5
CBR	1.24	1.29	1.35
IRR (%)		20.21	
	Apple		
	Assuming 10 percent higher total cost		
Discounted Rate (%)	10	8	5
NPV ($)	331.8	513.2	937.8
CBR	1.12	1.16	1.21
IRR (%)		16.25	
	Assuming 10 percent lower price of product		
Discounted Rate (%)	10	8	5
NPV ($)	274.4	432.7	803.6
CBR	1.11	1.15	1.19
IRR (%)		15.57	

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Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 107, No. 1, 2006, pages 19–32

Economic Assessment of Hazelnut Production and the Importance of Supply Management Approaches in Turkey

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Abstract

Turkey is the world's leading producer accounting for about 70% of world hazelnut supply. Hazelnut production is the single most important economic activity (monoculture) and income resource of rural households in the Black Sea Region. Hazelnut sector is supporting since 1962. However, due to inappropriate policies a stock problem has arisen in the sector. The Government has intervened to over production problem with various regulatory measures since 1989. However, results of supply response model showed that legal regulations have not any significant effect on reducing over production. Annual rate of increase of hazelnut production was calculated as 4.48%. And long term supply elasticity was found as 0.09 by Nerlove Model. The inelastic supply restricts the interventions on market by support price mechanism. However, high support prices and purchase guarantee keep farmers in hazelnut farming and encourage them to expand their production area. Monoculture is the most destructive factor which reduces all supply management initiatives. Government is both trying to keep farmers income at a certain level by high support prices, and also trying to apply supply control measures. This situation leads an intervention dilemma and creates a vicious cycle in hazelnut sector. Due to importance of Turkey in World hazelnut trade, it is necessary to solve over production problem in order to stabilize domestic and world prices. This research showed that the most effective way to supply control is to differentiate hazelnut farmer's income sources in order to encourage them to reduce their production area.

Keywords: hazelnut production, hazelnut policy, supply management, supply response

1 Introduction

Hazelnut was native to the black sea coast long before our era, not as a cultivated product but growing in the wild on trees or shrubs on the steep slopes of the mountains that are parallel to the coast for hundreds of kilometres from east to west. Hazelnut has

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been traded commercially for 600 years (Anonymous, 2001). Hazelnut production is a traditional crop, grown for centuries on productive costal, dry and marginal land largely concentrated in black sea region.

Hazelnut is not only one of the most important export crops of Turkey, but also the main economical activity of nearly 400,000 households under the form of family farming in the Black Sea Region (Anonymous, 2001). These aspects of hazelnut production, which fall within the framework of multi-functionality, are seen as being the key factors in maintaining social, economic and environmental sustainability in the rural parts of the region as well as urban areas due to the employment and trade benefits created by hazelnut processing industry. The hazelnut economy directly and indirectly supports 8 million people. Therefore, stability of hazelnut prices is an important issue. However, price stability depends on stability of output or stability of volume offered for sale.

The control of output in agriculture is subject to two considerable obstacles, the effect of natural conditions and the large number of producers. In the field of agriculture, physical control is clearly very difficult. In the case of fruit, where the trees in any given season cannot be increased or decreased in number, the output, as far as the short time is considered, is almost completely beyond the control of the producer (Wallace, 1951). Agricultural supply response is a very important issue in that it has an impact on growth, poverty and the environment. Agricultural supply response represents the agricultural output response to change in agricultural prices or to agricultural incentives (Mamingi, 1997). The price of an agricultural commodity is the main factor that affects agricultural output. In general, many authors use some distributed lags to capture price expectation (Behrman, 1968; Baritelle and Price, 1974; Bapna *et al.*, 1984; Mshomba, 1989; Sharma, 1992; Yavuz *et al.*, 2005). However, the lag structure may vary from one type of crop to another. Usually, one would expect perennial crops to have longer lags than annual crops. In some empirical studies, perennial crop supply was specified in terms of crop planting area and yield (Baritelle and Price, 1974; Caman and Green, 1991; Alston *et al.*, 1995; Roseen, 1999). In this study, hazelnut supply was specified in terms of production quantity.

In this study, the economic structure of Turkish hazelnut sector and supply control strategies has been examined briefly. The description the model and the data used estimation of the model parameters was explained in the third section of the article and then, growing trend of hazelnut and factors affected hazelnut supply has been modelled and results were discussed in final section.

2 Economic Structure of Turkish Hazelnut Production

The dynamics of world production and markets have not changed much in several decades. World hazelnut production in 2004 was 699,939 tones unshelled. Turkey is the largest producer (70%) and exporter of the world followed by Italy (12%), USA (5.7%) and Spain (2%). The world hazelnut production and export show fluctuations depending on the climatic conditions from year to year. World shelled hazelnut export is around 176,000 tones in 2004 and Turkey controlled 80 % of the commercial trade. The world supply of table hazelnut in shell does not exceed 15,000 tones, and the market is saturated enough. Germany is the most important hazelnut importer in the world and covers approximately 36 % of the total world import. Around 75 % of total exports go to European countries and Europe consumes 80% of world production (MARTI, 2001; SHEPARD, 2002). In addition, Turkey is currently trying to expand the markets in Asia, Turkic Republics, and Russia.

In Turkey, hazelnut is produced approximately on 570,000 ha land (TANRIVERMIŞ *et al.*, 2006). Growers generally have very small plots. Most eastern producers have an orchard the size of only 1-2.5 ha; on the other hand, some central and western farmers have 10-15 ha orchards. According to the results of General Agricultural Census in 2001, average hazelnut farm size is 1.34 ha in general. Hazelnut farms are 4 times smaller than the average farm size of Turkey which is 6.1 ha (SIS, 2004).

Hazelnut production is the single income source of 61% of the families in the Black Sea Region (TANRIVERMIŞ *et al.*, 2006). Monoculture is a dominant character in hazelnut and tea production activities. The share of hazelnut production value in total provincial crop production value is 60,3% in Giresun, 57,8% in Ordu, 32,1% in Trabzon, 24,3% in Bolu, 17,6% in Sakarya, 9,2% in Zonguldak, 7,3% in Artvin, and 6,2% in Samsun. The production and market risks are relatively high particularly in Giresun and Ordu provinces where the share of hazelnut in total crop production value is more than 50%.

Most farmers are part-time farmer who grow hazelnuts to supplement their primary income, with less than the 1.5 hectares, and use family labour. This low-cost labour is the most important element in the production process to obtain much lower production costs (TANRIVERMIŞ and GÜNDOĞMUŞ, 2001; TANRIVERMIŞ *et al.*, 2004). Sloped land and labour are the main inputs of hazelnut production and there is a very limited possibility to employ these two inputs in any other alternative area.

Hazelnut production regions are separated into 3 groups in Turkey (AÇIL, 1963; SARIMEŞELI, 1992; TANRIVERMIŞ, 1991; GENÇ, 1993; ANONYMOUS, 2001). The first standard production region covers the eastern part of the Black Sea Region. This region is also called as "old hazelnut production region". The second standard production region is the middle and western part of the black sea area. In this region, the hazelnut production history goes back to 40-50 years, thus the orchards are younger and more planned than the first standard region. Average yield of plantations is also higher in this region, and it leads to a rapid increase in production areas. The third region includes the other provinces where hazelnut grows (especially Bursa and Istanbul). The third region is not valuable for exporting and the most of products which are grown in this region is consumed without processing.

Hazelnut is produced in 33 provinces of Turkey, but economical production is realized by 13 provinces, which are located mostly in the first region. During the last 50 years while hazelnut production areas increased 2.5 fold, production quantity increased 200 fold (ANONYMOUS, 2001; TANRIVERMIŞ *et al.*, 2006).

3 Supply Control Strategies for Hazelnut Farming in Turkey

Due to socio-economic importance of the crop, hazelnut production has important political implications in Turkey. Hazelnut has been included to support program in 1962. In the past, the Turkish government has supported prices for hazelnut production by providing funds to Fiskobirlik (Union of Hazelnut Sales Cooperatives). Fiskobirlik has historically served as a conduit for Turkey's government policy decisions. As a result of historically high support prices, hazelnut area and production expanded. Hazelnut prices show variation through years. The pricing of the regulated product frequently occurs in political atmosphere (van Kooten and Taylor, 1989) and it makes more difficult to regulate the market. Free market prices are generally lower than Fiskobirlik's price. When stock quantity is high, free market prices go down up to 40% below than support price. Fluctuating prices damage farmer's income directly.

The domestic consumption quantity of hazelnut is not known due to lack of data. However, this amount is predicted approximately 35,000 tones per year (Tanrıvermiş *et al.*, 2006). Hazelnut production, export, domestic consumption and stock data have been given in Table 1. As an average 143,804 tones of hazelnut surplus had to be stocked every year. As a result of inappropriate policies since 1923, hazelnut production areas shifted from sloped areas to first and second class farmlands and over expansion in production area could not be controlled.

Table 1: Hazelnut production, export, domestic consumption and stocks of Turkey

Years	*Production (tone/in shell)*	*Export (tone/shelled)*	*Domestic Consumption (tone/shelled)*	*Stock (tone/in shell)*	*Ratio of Stocks in Production (%)*
1980	302,461	99,219	16,500	37,350	12.35
1985	179,739	108,315	30,000	52,999	24.59
1990	374,566	195,645	30,000	272,296	72.70
1995	474,044	241,436	30,000	61,851	13.05
2000	467,719	177,307	35,000	273,871	58.55
2001	618,919	258,124	40,000	203,145	32.82
2002	620,000	252,779	40,000	229,904	37.08
2003	450,000	220,938	35,000	189,676	42.15
Average of 1964-2003	324,277	140,079	28,521	143,804	% 41

Source: (Tanrıvermiş *et al.*, 2006)

Supply management has to be applied in order to cope with excess supply problem. Supply management has referred to a variety of systems to decrease supplies from government purchasing of surplus stocks to providing financial incentives to reduce production (Levy, 2000). In general, supply control measures can be listed as; import control, government purchasing of surplus stocks, acreage controls, providing financial incentives to reduce production, and use of quotas that assign a given amount of product to each (Brandow, 1960; van Kooten and Taylor, 1989; USDA, 1999; Levy, 2000). Different kinds of supply control methods were implemented especially by Canada, the EU member states and USA up to date (Moschini, 1988; USDA, 1999; Tolman, 2002).

In general, import restriction is the first step in supply control. However, in Turkish hazelnut sector there is already no significant import. Thus this measure is not valid for this sector.

In Turkish hazelnut sector a combination of supply control methods have been applied in different periods. These are summarized below:
Government purchasing of surplus stocks; Fiskobirlik is the most important organization of the sector and it aims to stabilize hazelnut prices by withdrawing the surplus product. Fiskobirlik support policy is to buy unlimited quantities of product from producers with an intervention price which is fixed for each production year. However, today the funds of and quantity purchased by Fiskobirlik has reduced. In 2000, the Turkish government reorganized the activities of Agricultural Sale Cooperatives including Fiskobirlik by giving them autonomy and separating their procurement and processing functions by the law of Agricultural Sales Cooperatives and Unions Nr. of 4572 (TANRIVERMIŞ *et al.*, 2006; USDA, 2005). Starting in 1999, with pressure from the World Bank and International Monetary Fund (within the framework of agricultural reform implementation project (ARIP) and stand-by agreement), Turkey has progressively reduced these intervention prices.

Acreage control is a widespread method that governments of many countries resort to in order to cope with over-production. The Turkish Government made a number of legal arrangements in order to regulate and control hazelnut production. A law number of 2844 "Planning of Hazelnut Production and Determination of Hazelnut Production Areas" dated 1983 put into practise and the regulation on "Planning of Hazelnut Production and Determination of Hazelnut Production Areas" came into force in 1989. On 3 February 1993 hazelnut plantation areas were restricted with 13 provinces by the Decision Nr. 93/3985 of Ministry Council. Hence, the plantation of new hazelnut orchards is subject to official permission.

In 1994, Government was decided to pay compensation to the farmers who remove their own hazelnut orchards before completing their economical life by Decision Nr.94/6519. This Decision covers the farmers who have orchards in the first and second classes agricultural lands and in the third class agricultural lands that have less than 6% slope in the provinces that were permitted by Decision Nr. 93/3965.

The farmers were also encouraged to grow other alternative products. In this respect, the Decision Nr. 24382, "Determination of Hazelnut Production Areas and Supporting the Farmers who Remove their Hazelnut Orchard and Plant any Alternative Product instead of Hazelnut" was published and came into force in 2001.

Production quotas have not implemented in the sector yet. Production quotas have been implemented for a long time on some annual crops such as sugar beet, and tobacco in Turkey.

Storage would also be desirable to assure adequate market supplies in years of short crops. Thus storage program to stabilize annual supplies would be one adjunct to supply control (BRANDOW, 1960). However for perennial crops, storage would not be an appropriate policy tool for controlling and eliminating overproduction in short-term due to the long productive life of plants. In fact, the conditions of storage facilities may cause high level losses and increase production cost. In reality, storage of hazelnut in the region is not seen as a suitable policy of supply control due to the technical and economic consequences.

In some countries there is too much supply control, but not enough demand control. In Turkey, Hazelnut Promotion Group (HPG) has been established with the joint initiatives of Fiskobirlik, Undersecretariat of Treasury and Black Sea Chambers of Exporters. The main objective of HPG was to promote both domestic and international demand of hazelnut. With this purpose, the Group has prepared generic advertising program and applied a common promotion plan. The first result of hazelnut promotion was good and it was declared that 30% demand increase was observed in new foreign markets after a year of promotion (ANONYMOUS, 2002).

4 Data and the Models

The data used in the study were obtained from various publications of the State Institute of Statistics (SIS) of Turkey and Fiskobirlik's publications. The time series data covers the period between 1950 and 2004. Data set was also arranged according to each Standard Production Region as both time series and panel data.

Trend equation and annual average rate of increase for production area, quantity and yield was estimated by using equation (I) (SNEDECOR and COCHRAN, 1980; ERTEK, 1987; GÜNES and ARIKAN, 1988).

$$W = a\,b^t \tag{1}$$

Where a and b are constants to be estimated and t denotes time.
Applying logarithms to the equation results:

$$\log W = \log a + (\log b)\,t \qquad \text{or} \tag{2}$$

$$Y = \alpha + \beta t \tag{3}$$

where: $Y = \log W$; $\alpha = \log a$ and $\beta = \log b$. If $\log W$ instead of W is plotted against t, the graph will be linear.

This equation was used for three data sets respectively: Y_a denotes production area (ha), Y_q is production quantity (tonne) and Y_y is yield (kg/ha). Coefficients were estimated by SPSS 11.5 statistical package program.

Regional differences in production area, quantity and yield according to three standard production regions were determined by using dummy variables. ANOVA model was used for this purpose. In this model, panel data set was used in order to reduce the effect of time (GUJARATI, 1992; BALTAGI, 1996). The model is given below:

$$Y_i = \alpha_1 + \alpha_2 D_2 + \alpha_3 D_3 + u \tag{4}$$

where:
Y_i: production area, quantity and yield respectively,

D: dummy variable:

$$D_2 = \begin{cases} 1 & : \quad (if\, 2^{nd}\, Region) \\ 0 & : \quad (other) \end{cases} \quad D_3 = \begin{cases} 1 & : \quad (if\, 3^{rd}\, Region) \\ 0 & : \quad (other) \end{cases}$$

and $\left(\frac{\alpha_i}{\alpha_1}\right)$ denotes changing ratio according to the regions.

In the supply response model, total production quantity (Q_t) has been taken as dependent variable. Price is compatible with supply theory and is therefore used as the independent variable. Plantation of new trees is the function of future expected prices. Future expected prices were a function of a finite number of past prices (Baritelle and Price, 1974). Thus, lagged prices were included in the model. The length of the individual past years price lag left to statistical estimation process.

There are two different prices valid in hazelnut sector; support price (SP) which is declared by the government via Fiskobirlik and free market price (FM) which is constituted around support price. Correlation between the two prices is high (0.80). This high correlation coefficient may cause an imperfect multicollinearity problem in the model, if both of them are used together as independent variables. For this reason, only support price was included the model.

Support purchase, export and stock quantities and export price have been taken as independent variables. These variables were used in the model with one year lagged values. Weather conditions and regulatory supply management measures have been used as dummy variables. Among agro climatic factors, freeze is likely to be the most decisive for hazelnut supply response.

Data set has covered the period between 1950 and 2004. Consumer Price Index (CPI) was used to obtain real price level. The real prices are given as:

$$P^R = \frac{CPI_b}{CPI_c} \times P_c \tag{5}$$

where P^R is real price, CPI_c is the current year's consumer price index, CPI_b is the base year consumer price index and P_c is the current price.

$$\begin{aligned} Q_t \quad = \quad & a + b_1 SPQ_{t-1} + b_2 EQ_{t-1} + b_3 \frac{EP_{t-1}}{CPI} + b_4 S_{t-1} + \sum_{n=5}^{11} b_n \sum_{t=1}^{T} \frac{SP_{t-T}}{CPI} + \\ & b_{12} D_{FR} + b_{13} D_{89} + b_{14} D_{93} + b_{15} D_{94} + b_{16} D_{01} + e \end{aligned} \tag{6}$$

where:
SPQ: support purchase quantity (tone/year)
EQ: export quantity (tone/year)
EP: export price ($/tone)
S: annual stock quantity (tone/year)
SP: Support Price (TL/kg)
D_{FR}: Dummy, freeze
D_{89}: Dummy, year 1989, regulation on determination of hazelnut production areas

D_{93}: Dummy, year 1993, regulation on restriction of hazelnut production areas
D_{94}: Dummy, year 1994, regulation on compensation of producers
D_{01}: Dummy, year 2001, regulation on alternative crop
The long run supply elasticity was calculated by Nerlove's supply response model. The Model consists of the three equations:

$$A_t^* = \alpha_0 + \alpha_1 P_t^* + u_t \tag{7}$$

$$P_t^* = P_{t-1}^* + \beta(P_{t-1} - P_{t-1}^*) \tag{8}$$

$$A_t = A_{t-1} + \gamma(A_t^* - A_{t-1}) \tag{9}$$

where A_t and A_t^* are actual and desired area under cultivation at time t, P_t and P_t^* are actual and expected price at time t and β and γ are the expectation and adjustment coefficients, respectively. Elimination of the unobservable variables A_t^* and P_t^* leads immediately to the reduced form:

$$A_t = b_0 + b_1 P_{t-1} + b_2 A_{t-1} + b_3 A_{t-2} + u_t$$

with $b_0 = \alpha_0\,\beta\,\gamma$, $b_1 = \alpha_1\,\beta\,\gamma$, $b_2 = (1-\beta) + (1-\gamma)$, $b_3 = -1(1-\beta)(1-\gamma)$ and $u_t = \gamma(u_\tau - (1-\beta)\,u_{t-1})$ from which the key parameter α_1 may be retrieved by means of the identity $\alpha_1 = b_1(1 - b_2 - b_3)$. The long term price elasticity ε is then usually calculated as

$$\varepsilon = a_1 \frac{\overline{P}}{\overline{A}} = \frac{b_1\,\overline{P}}{(1 - b_2 - b_3)\,\overline{A}}$$

where $\overline{P}$ and $\overline{A}$ represent historical mean of prices and acreage under cultivation, respectively (Nerlove and Addison, 1958; Braulke, 1982; Begum *et al.*, 2002).

5 Results and Discussion

According to calculated trend results (Table 2), annual average increase rate of hazelnut production areas, production quantity and yield of Turkey are; 1.79%; 4.48% and 1.30% respectively. Difference between hazelnut production regions is statistically important (Table 3) and the highest increase rate of production area and quantity is observed in second production region. This region stimulates Turkish hazelnut production increase and it is recommended that the main supply control mechanism should be intensively applied in this region.

Results of supply response model (Table 4) showed that while one year lagged export price and four years lagged support price increase hazelnut production, one year lagged stock quantity and negative weather conditions (freeze) decrease hazelnut production. Baritelle and Price (1974) found the lag length as 8 years for apples. Yavuz *et al.* (2005) found the lag length as 5 years for hazelnut supply response. Thiele (2002) indicate that negative weather conditions are very important in supply response. In his study, it was found that among the non-price factors, freeze has significantly impaired agricultural growth.

Table 2: Trends according to regions ($W = a\,b^t$)

	Turkey	*Region 1*	*Region 2*	*Region 3*
		Production area (ha)		
$\log a$	5.1450*	5.1340*	4.0500*	2.2750*
A	139636.8200	136144	11220	188.3600
$\log b$	0.0077*	0.0037*	0.0225*	0.0191*
B	1.0179	1.0080	1.0530	1.0450
R^2	0.934	0.6480	0.9500	0.8140
F	706.2500	91.9800	950.4850	218.7400
		Production quantity (tonne)		
$\log a$	4.8140*	4.7510*	3.9550*	2.4290*
A	65162.8300	56363	9015	268.5300
$\log b$	0.0190*	0.0149*	0.0307*	0.0196*
B	1.0448	1.0350	1.0730	1.0460
R^2	0.7960	0.6540	0.8790	0.8670
F	195.6040	94.6560	363.1790	326.1960
		Average yield (kg/ha)		
$\log a$	1.9520*	1.6170*	1.9050*	2.1540*
A	89.5400	41.3900	80.3500	142.5600
$\log b$	0.0054*	0.0112*	0.0082*	0.0005
B	1.0130	1.0260	1.0190	1.0000
R^2	0.4380	0.5130	0.4150	0.0040
F	38.8920	52.7070	35.4180	0.1940

* Statistically significant at 1 % level

Table 3: Regional differences (ANOVA Model)

	α_1	α_2	α_3	R^2	F
Production Area (Y_a)	171379.29*	-115247.40*	-166764.30*	0.83	382.74
Production Quantity ($Y_{\ddot{u}}$)	161040.40*	-71018.54*	-159960.00*	0.50	77.40
Average Yield (Y_v)	91.27*	50.38*	60.94*	0.24	24.11

* Statistically significant at 1 % level

Table 4: Estimated results for supply response model

Variables	β	*Std. Error*	t	*Sig.*
Constant	57723,353	22342.681		2.584
SPQ	2847,738	7486.179	0.049	0.380
EQ	0.050	0.200	0.043	0.250
EP	102.151	34.287	0.354	2.979
S	-0.287	0.128	-0.162	-2.236
D_{FR}	-63702.145	24943.492	-0.176	-2.554
D_{89}	62078.408	38387.735	0.175	1.617
D_{93}	62186.578	77123.487	0.159	0.806
D_{94}	-80697.257	69713.878	-0.199	-1.158
D_{01}	52549.674	67916.597	0.088	0.774
SP_{lag1}	-5041.928	10224.583	-0.084	-0.493
SP_{lag2}	9124.270	8867.255	0.156	1.029
SP_{lag3}	-7714.978	8786.891	-0.135	-0.878
SP_{lag4}	22539.579	9562.314	0.399	2.357
SP_{lag5}	4370.888	10291.200	0.078	0.425
SP_{lag6}	-6539.788	10493.394	-0.111	-0.623
SP_{lag7}	10424.781	8511.224	0.166	1.225

According to results of supply response model, regulatory measures of government have not any significant effect on supply control.

Formulation of an appropriate agricultural price policy for growth and stability requires an understanding of the long term effects of price changes upon producers and consumers (Nerlove and Addison, 1958). Long term supply elasticity of hazelnut production was found as 0.09 by using the Nerlove Model. This highly inelastic supply showed that overproduction can not be explained only high support prices and price control will not be very effective in controlling output. On the other hand it is a fact that a historically high support price is the most important reason which promotes small-scale farmers to continue their production.

There is an intervention dilemma in hazelnut sector. Turkish Government has tried to apply both support and supply control mechanisms at the same time. It was necessary to support prices in order to keep farmer's income at a certain level. On the other hand long term support policies stimulate overproduction and depressed prices. Depressed prices forced Government to support farmers again and this situation has created a vicious cycle in the sector. The base of the problem is monoculture. Small scale farmers have no other alternative except for hazelnut farming and they had to increase their production area in order to increase their family income.

Recent years, Turkish Government has begun to reduce its interventions and support prices by the conditions of ARIP and stand-by agreements under the auspices of IMF and the World Bank. However due to explanations above it is expected that reduced support prices will not do any important implication on over supply.

Actually government intervention may be sufficient to prevent the over production under monopoly conditions (van Kooten and Taylor, 1989). But the hazelnut sector does not have a monopoly character and there are two prices and alternative sale options in the market as mentioned before.

This results show that the best way to break this vicious cycle and cope with over supply problem is to create new agricultural and/or off-farm income sources. In this respect, incentives and encouragement to organic hazelnut production is accepted as another way to control supply. According to the research results carried out at farm level, transition to organic industry from conventional farming is economically, socially and ecologically viable. It is interesting that average yield and net profit per hectare of planted land is higher than conventional farming in the region (Bülbül, 2002). In addition to the development of organic industry in the region, cultivation of some new crops should be encouraged on farms within the framework of agricultural and rural policies. Hazelnut growers have a tendency to adopt kiwifruit plantation on farms and the research results indicated that labour requirements, gross and net profit per planted area of kiwifruit is more than and hazelnut farming (Tanrivermiş *et al.*, 2006). In fact, the development of new cultivation should be parallel to the domestic and external demand in order to solve surplus of products.

An appropriate alternative is to provide incentives for non-farm activities of hazelnut producers' in order to develop agricultural and non-agricultural activities such as rural tourism, rural industrialization, handicraft activities and agricultural activities other than hazelnut growing like fisheries, forest products and animal products production etc. in the region. Therefore, improvement of living standards and/or stabilization of farm/household incomes should be achieved through differentiations of income sources. Through these means, dependency of economic and social life on hazelnut farming, processing and trade will be decreased and the impacts of monoculture will be mitigated.

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Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 107, No. 1, 2006, pages 33–40

Crop Coefficient of Haricot Bean at Melkassa, Central Rift Valley of Ethiopia

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Abstract

Crop coefficient (K_c), the ratio of potential crop evapotranspiration to reference evapotranspiration, is an important parameter in irrigation planning and management. However, this information is not available for many important crops. A study was carried out at the experimental farm of Melkassa Agricultural Research Center of Ethiopian Agricultural Research Organization, which is located in a semi arid climate. Four drainage type lysimeters were used to measure the daily evapotranspiration of haricot bean, *Awash Melka* variety on a clay loam soil. Crop coefficient was developed from measured crop evapotranspiration and reference evapotranspiration calculated using weather data. The measured values of crop coefficient for the crop were 0.34, 0.70, 1.01 and 0.68 during initial, development, mid-season and late-season stages. These locally determined values can be used by irrigation planners and mangers at Melkassa and other areas with similar agroecological conditions.

Keywords: crop coefficient, Ethiopia, haricot bean, lysimeter

1 Introduction

Decisions related to agricultural water management such as irrigation scheduling, water resources allocation and planning require the information about the water loss for a given crop. This water loss from a given cropped plot of land can be determined from the knowledge of reference evapotranspiration (ET_o), potential evapotranspiration (ET_c), and crop coefficient (K_c).

Most methods of estimating evapotranspiration involve two steps; first, evapotranspiration for a well watered reference crop (grass or alfalfa) with standard canopy characteristics (ET_o) is estimated (Burman *et al.*, 1980; Doorenbos and Pruitt, 1977). Currently, the FAO Penman-Monteith method is recommended to estimate ET_o (Allen *et al.*, 1998). Then evapotranspiration for the crop being considered (ET_c) is obtained by multiplying ET_o by a crop coefficient (K_c) which varies by growth stage for each crop.

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Crop coefficient represents crop specific water use and is essential for accurate estimation of irrigation requirement of different crops in the command area. It serves as an aggregation of the physical and physiological differences between crops and the reference definition. The variation of the crop coefficient during a growing season is obtained experimentally (BURMAN *et al.*, 1980; DOORENBOS and PRUITT, 1977; JENSEN, 1974; PRUITT *et al.*, 1972, 1987; WRIGHT, 1982). Although there are published K_c values for different crops, these values are commonly used in places where local data are not available. As these values vary from place to place and from season to season, there is a strong need for local calibration of crop coefficients under given climatic conditions (TYAGI *et al.*, 2000). There is, therefore, a pressing need to experimentally measure crop coefficients locally, so that project managers can correctly be advised.

Haricot bean (*Phaseolus vulgaris*), the subject crop of this research, is a well-established component of Ethiopian agriculture. From the export of white seeded beans, Ethiopia on average obtains about 16 million USD, out of which Awash Melka, the famous exportable variety used in this study, contributes the major portion (MARC, 2001). The middle rift valley of Ethiopia contributes about 60% of haricot bean production in the country. However, unreliable and poor distribution of rain is one of the major causes for low yield of haricot bean in this area (IAR, 1990). At present, farmers are opting for the production of this crop under irrigation. However, the water requirement data and crop coefficient of this crop is not locally available. Hence, knowledge of experimentally determined K_c value is important for proper irrigation scheduling and efficient water management of the selected crop variety. Therefore, this study was undertaken with the objective of developing crop coefficient for different growth stages of haricot bean.

2 Materials and Methods

2.1 General description of the study area and experimental lysimeters

This research was conducted on four lysimeters at Melkassa Agricultural Research Center, Central Rift Valley of Ethiopia. The center is located at an elevation of 1550 m above sea level with latitude of 8°24' N and longitude of 39°21' E. The average annual rainfall in the area is 768 mm, which is erratic and uneven in distribution. The site has a mean maximum temperature of 28.5°C and mean minimum temperature of 12.6°C. Loam and clay loam soil textures are the dominant soils of the area.

The experimental lysimeters are located near the agrometeorological station of the research center. The lysimeters were of non-weighing type each having an access chamber for aeration and underground steel pipes for disposal of drainage water from the lysimeters. These pipes are connected to water collecting tank mid way between the four lysimeters. Rim of each lysimeter protrued 10 cm above the soil surface so that no surface water runon or runoff may occur. One access tube for each lysimeter was installed at the center down to 90 cm depth.

2.2 Crop detail

The well known haricot bean variety in the area, *Awash Melka*, was sown on November 21, 2004 in and out of the lysimeters in all directions to have similar environment as in normal fields and decrease advective effects. Before sowing, all the four lysimeters were made to have the same moisture content. The crop was harvested on March 7, 2005.

The row spacing and plant spacing were 40 cm and 10 cm respectively. Recommended doses of fertilizers of 100 kg/ha Urea and 100 kg/ha DAP were added to increase yield and obtain reasonable K_c value. Plant height was measured at each growth stage by taking representative 5 plants from each plot and measuring from the bottom at soil surface to the tip. Leaf area index (LAI) was monitored. The leaf area index (LAI) was determined as a ratio of leaf area per unit area of soil below it by taking representative 5 plants from each plot at different times during the growing season.

2.3 Measurement of soil moisture and irrigation application

Soil samples were collected at interval of 30 cm up to 90 cm depth for determination of some soil physical properties like field capacity, permanent wilting point, bulk density and texture. The average field capacity and permanent wilting points of the root zone profile were 31.6% and 15.0% respectively. The bulk density was 1.1 g/cm^3. Neutron probe was used to monitor the soil moisture content. The probe was calibrated following standard procedure for neutron probe calibration by plotting the results of neutron probe reading and gravimetric sampling around the access tube. The moisture content was monitored at intervals of 30 cm up to 90 cm soil depth at different times during the growing season.

Irrigation water was applied to the crop when there was 30% depletion of the available soil moisture within the crop root zone (Doorenbos and Kassam, 1979). Similar irrigation amount at this depletion level was given to the crop in and out side the lysimeter to ensure uniform plant growth. The application of irrigation was carried out in known volume of buckets by converting the 30% depletion in terms of volume. Irrigation was terminated at crop maturity.

2.4 Determination of crop coefficient

Ideally, ET_o of the reference crop should be experimentally measured with a lysimeter. However, the alternative procedure is to determine ET_o from climatic data using the FAO Penman-Monteith method once the necessary variables specific to the location are determined. In this study, ET_o was calculated using FAO Penman-Monteith Equation (ALLEN et al. 1998) using weather data of the Melkassa weather station. The crop evapotranspiration for each growth stage of the crop was calculated by using water balance equation as:

$$ET_c = I + R - D + S \tag{1}$$

where ET_c: crop evapotranspiration (mm); I: irrigation (mm), R: rain fall (mm), D: drainage collected (mm), and S: decrease in storage of soil moisture (mm).

The crop coefficient value over a given period, such as decade, physiological growth stage or whole season, was then calculated as:

$$K_c = \frac{ET_c}{ET_o} \tag{2}$$

where K_c: crop coefficient; ET_c: crop evapotranspiration, and ET_o: reference crop evapotranspiration.

3 Results and Discussion

Crop evapotranspiration in 10 day intervals (decades) was calculated for each lysimeter using the water balance equation, Eq. (1). The result of the average of the four lysimeters is presented in Table 1. It can be observed from the Table that the peak water demand occurred almost three months after planting and only two weeks before harvest.

Table 1: Average potential crop eavpotranspiration, reference crop evapotarnpiration and crop coefficient values on 10-day interval basis.

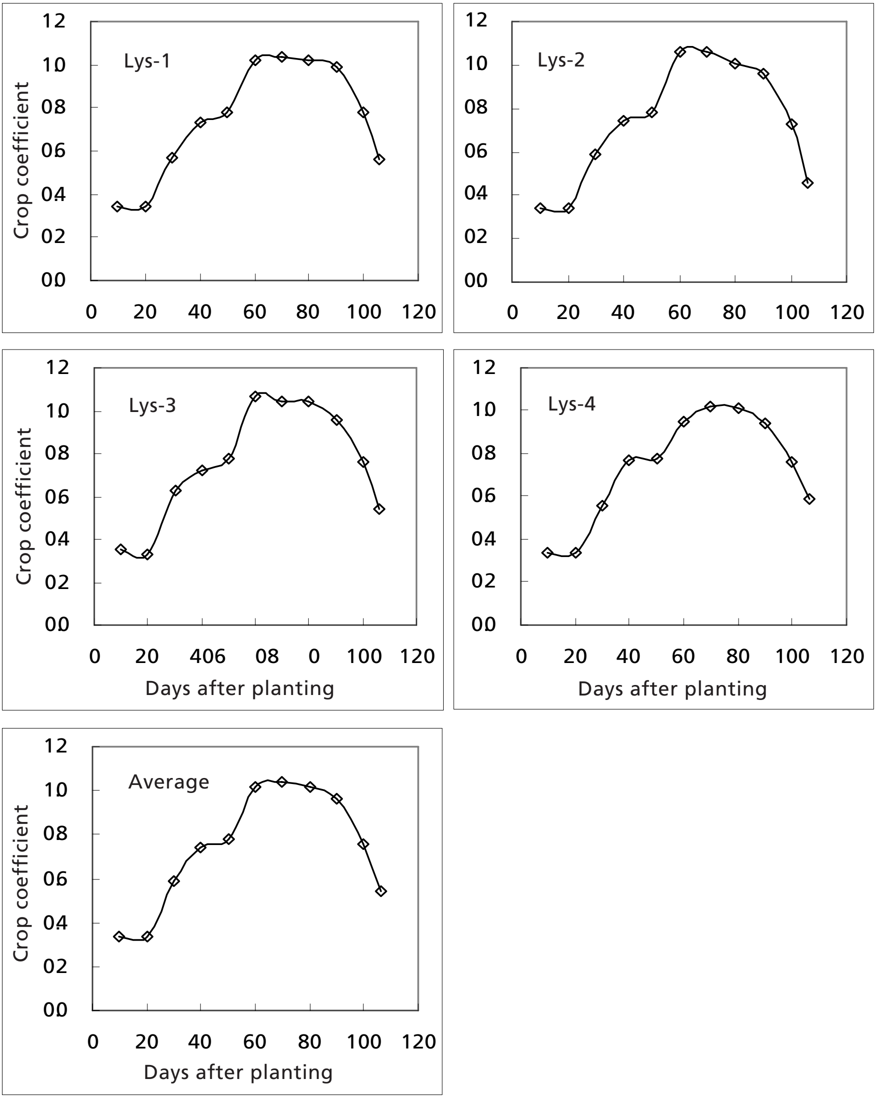
Days after planting	*Crop evapotranspiration* ET_c *(mm)*	*Reference evapotranspiration* ET_o *(mm)*	*Crop coefficient* K_c
10	17.87	51.72	0.34
20	17.83	52.38	0.34
30	34.12	57.85	0.59
40	36.79	49.71	0.74
50	40.04	51.30	0.78
60	47.76	46.62	1.02
70	53.91	51.90	1.04
80	64.49	63.06	1.02
90	68.57	71.17	0.96
100	46.63	61.46	0.76
106*	19.15	35.37	0.54

* row was calculated for 6 days period.

Crop coefficient values of haricot bean were obtained by dividing crop evapotranspiration measured by lysimeter with reference evapotarnspiration, Eq. (2). Fig. 1 presents the seasonal evolution of crop coefficient values in each lysimeters calculated for decades (ten-day period). There is a general trend of K_c increment from initial stage to end of development stage and in the midseason stage the curves show almost constant values. As the results of water balance analysis showed no stress periods, the scatter of points can be assumed to be normal for an experimental data.

The evolution of K_c values reflected the effects of crop development and physiology on ET_c. Fig. 2. shows the general trend of ET_c and ET_o values of haricot bean calculated as average value of the four lysimeters.

Figure 1: Ten-day period K_c curves of haricot bean at Melkassa (Lys-1, Lys-2, Lys-3, and Lys-4 and refer to lysimeters 1, 2, 3, and 4 reservedly).



The observed growth stages of haricot bean at Melkassa were 20, 30, 40, and 16 days during initial, crop development, midseason and late season growth stages. The total growth cycle is 106 days. The values of crop coefficients calculated for each growth stage of haricot bean are presented in Table 2.

Figure 2: Average evapotranspiration values at Melkassa.

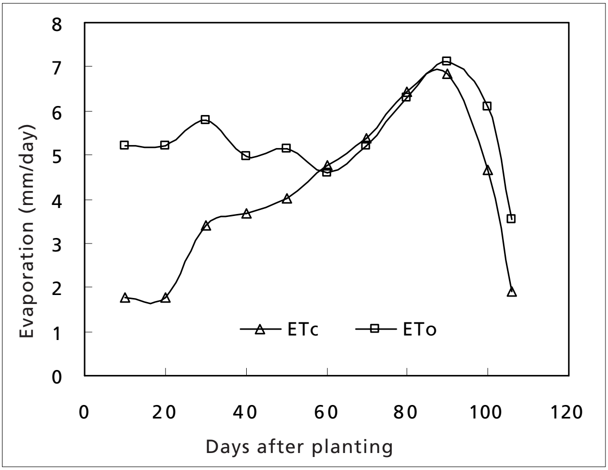


Table 2: Growth stage-wise K_c values of haricot bean at Melkassa.

	Initial stage	*Development stage*	*Mid season stage*	*Late season stage*
Duration (day)	20	30	40	16
ET_c (mm)	35.61	110.96	234.74	65.78
ET_o (mm)	104.10	158.86	232.75	96.83
K_c	0.34	0.70	1.01	0.68

The increase in K_c value from initial stage up to midseason stage is due to increase in ground cover of the crop, which has impact on evapotranspiration. During this stage, leaf area is small and evapotranspiration is mainly in the form of soil evaporation. This stage is terminated when 10% of the ground is covered (Allen *et al.*, 1998). As the crop develops and shades the ground to effective full cover and reach full size with increasing LAI, plant height and root depth, the amount of water abstraction increased which in turn increased the evapotranspiration. The evolution of ET_c indicated that maximum crop water requirement occurred at the end of the midseason stage, when evaporative demand was high. From the midseason stage to late season stage, there was a general decline in K_c. This decline is attributed to leaf senescence and to completion for assimilates between leaves and seed. Senescence is usually associated with less efficient stomatal conductance of leaf surfaces due to the effects of ageing, thereby restricting transpiration and causing a reduction in crop coefficient. Crop coefficient value at late season stage reflects crop and water management practices hence the crop at this stage need not get frequent irrigation as evaporation becomes restricted.

It can be observed that there is a slight variation in K_c values between the lysimeters observed during the crop development, midseason and late season stages. The computed overall average K_c values during initial, crop development; midseason and late season stages were 0.34, 0.70, 1.01 and 0.68 respectively. K_c value at the end of the growing season (harvest) was found to be 0.54. The K_c values for this crop given by WRIGHT (1982) at Kimberly, Idaho for initial, midseason and end of season stage were 0.15, 1.19 and 0.35. The K_c values suggested by ALLEN *et al.* (1998) for dry bean were 0.40, 1.15, and 0.35 for the initial, midseason and end of season. The differences of K_c values of the crop at different stages in different areas emphasize the need for local calibration of K_c values.

Some of the observed agronomic parameters (yield, LAI and plant height) of the crop are presented in Table 3. From the table, it can be observed that LAI and plant height increased as the crop passes through the different growth stages and reached maximum at the beginning of the midseason stage. Then after it decreased due to maturity of the crop associated with leaf ageing, senescence of leaves and leaf drop.

The recommended yield of this crop is 2500 kg/ha which is quite close to the observed average yield in this study. There is not as such significant difference in yield between the lysimeters indicating that the crop in each lysimeter has got the same amount of irrigation water at its depletion and the same amount of recommended doses of fertilizer.

Table 3: Agronomic parameters of haricot bean at Awash Melkassa.

Experimental Lysimeter	*Agronomic parameter*	*Initial stage*	*Development stage*	*Mid season stage*	*Late season stage*
Lys-1	Plant height (cm)	12.0	25.2	65.0	65.0
	LAI	0.70	2.00	3.50	1.50
	Yield (kg/ha)				2500.0
Lys-2	Plant height (cm)	12.20	25.8	65.5	66.0
	LAI	0.71	2.20	3.70	1.60
	Yield (kg/ha)				2520.0
Lys-3	Plant height (cm)	11.8	24.6	63.0	63.5
	LAI	0.70	2.10	3.40	1.30
	Yield (kg/ha)				2503.0
Lys-4	Plant height (cm)	12.2	25.5	64.0	64.0
	LAI	0.70	2.30	3.60	1.40
	Yield (kg/ha)				2510.0
Average	Plant height (cm)	12.1	25.4	64.4	64.6
	LAI	0.70	2.15	3.55	1.45
	Yield (kg/ha)				2508.3

4 Conclusion

From the study, it has been shown that estimates of crop water requirement made with locally determined crop coefficients slightly differ from estimates published in literature (e.g. ALLEN *et al.* (1998)). This emphasizes the strong need for local calibration of K_c for each variety. The fact that ET_c was measured locally makes the K_c values locally calibrated. Although the values may not be exactly the same as would be obtained with measured ET_o, they should be accurate enough for the purpose of estimating crop water requirements in the climatic region. ET_c and K_c are some what dependent on water management, i.e., operational criteria of irrigation system/method and amount of water supplied, variety, climate, location and other cultural differences. Thus, the K_c values obtained at in this study at Melkassa can be beneficial to areas with similar agroclimatic condition as that of Melkassa.

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Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 107, No. 1, 2006, pages 41–54

Influence of Cereal-Legume Rotation on *Striga* Control and Maize Grain Yield in Farmers' Fields in the Northern Guinea Savanna of Nigeria

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Abstract

On-farm trials were conducted in 2001, 2002, and 2003 in the northern Guinea savanna of Nigeria to evaluate integrated *Striga hermonthica* control measures under farmer-managed conditions. These included intercropping a *Striga*-resistant maize variety with cowpea for 3 years and also cropping this maize in rotation with legume trap crops - soybean and cowpea for 1-2 two years. Intercropping *Striga*-tolerant maize variety, Acr. 97TZL Comp. 1-W, with cowpea (*Vigna unguiculata* L.) consistently reduced *Striga* infestation in maize relative to continuously cropped sole maize over the three-year period. Maize grain yield was lower in the intercrop than in the sole maize plot probably due to competition from cowpea. However, because of the high value of cowpea in the intercrop, crop value for this system was higher than sole cropped maize. Legume-maize rotation reduced *Striga* infestation by 35% after one year of legumes in the rotation and by 76% after two years of legumes in the rotation. Soybean was more effective in reducing *Striga* infestation and also gave higher maize grain yield than cowpea. The rotation of these two legumes with maize had clear advantage over continuously cropped maize. Farmers should therefore be encouraged to adopt the introduction of grain legumes into the cereal cropping systems of the Nigerian savanna.

Keywords: maize, soybean, cowpea, cereal-legume rotation, intercropping, *Striga*

1 Introduction

The parasitic angiosperm, *Striga hermonthica* (Del.) Benth is an important weed mainly of C_4 cereals in the semi-arid tropics. Maize, sorghum, and millet are the most important hosts. The parasite can also infect upland rice. It has been estimated that about 40 to 70 million ha are severely or moderately infested in West African countries (Lagoke *et al.*, 1991). Severe *Striga* infection can cause 70 - 80% crop loss in maize and sorghum and losses can be much higher under heavy infestations, even resulting in total crop failure (Riches *et al.*, 1992; Parker and Riches, 1993). Farmers often have to abandon in-

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fested agricultural lands as a result of high soil infestation by *Striga* (Kroschel, 1999). Recent trends away from traditional prolonged fallow and intercropping towards continuous cereal monocropping to meet the needs of increasing population have intensified the Striga problem. In addition to many factors already known, grazing cattle, crop seeds, and wind contribute to the spread of *Striga* infestation to new areas (Berner *et al.*, 1996). The *Striga* problem is compounded by the plant's reproductive capacity. A single plant can produce over 50,000 seeds, which can remain viable in the soil for 15-20 years (Musselman, 1987; Doggett, 1988).

Striga research in Africa has a long history and a range of effective component control technologies has been identified (Parker and Riches, 1993). Examples of control options for *S. hermonthica* range from the use of leguminous trap-crops to stimulate suicidal germination of *Striga* seeds and therefore reduce the seed bank and improve soil fertility, to the use of resistant host-crop cultivars. Schulz *et al.* (2003) found that resistant maize following a soybean trap-crop yielded 1.58 t ha^{-1} of grain and outyielded farmers' maize variety following traditional practices by more than 80%. The effectiveness of leguminous trap-crops in reducing the *Striga* seed bank was demonstrated by Sauerborn (1999) in field experiments in Ghana where annual double cropping of trap-crops (soybean, sunflower and cotton) reduced the seed bank by about 30% each year. Similarly, Schulz *et al.* (2003) achieved 50% seed bank reduction after one year's rotation with soybean and cowpea under farmer-managed conditions. Carsky *et al.* (2000) reported that *S. hermonthica* incidence in maize after soybean, compared to maize after sorghum, was significantly reduced from 3.2 to 1.3 emerged plants per maize plant, resulting in greatly improved grain yields.

In addition to host-plant resistance and legume trap-crops, a substantial amount of work has been carried out to study the effect of soil fertility on *Striga* infestation. Infestation is frequently associated with low soil fertility (Carsky *et al.*, 2000; Schulz *et al.*, 2003). Hence, improved soil fertility conditions are likely to lead to reduced infestation (Debra *et al.*, 1998). The use of grain legumes can contribute to soil N (Carsky and Iwuafor, 1999). Estimates of fertilizer replacement values in a monomodal savanna zone of West Africa were 20 kg N ha^{-1} from soybean and 45kg N ha^{-1} from cowpea (Kaleem, 1993; Carsky *et al.*, 1997). Sanginga *et al.* (21001) reported that the grain yield of maize grown after soybean was increased by an average of 25% across two locations. They attributed this to enhanced N availability following soybean and other rotation effects, such as the reduction of soil-borne diseases. Intercropping, particularly of cereals with cowpea (*Vigna unguiculata*), is a common practice in many parts of the semi-arid zone. This is because food production is diversified, the risk of crop failure reduced, and resources for crop growth are utilized more efficiently compared to sole cropping (Carsky *et al.*, 1994). Intercropping of cereals with legumes has also been proposed as a means of suppressing *Striga* in the cereal crop (Vernon, 1995; Kureh *et al.*, 2000). Carson (1989) found that the density of emerged *Striga* plants, and soil temperature were both reduced when sorghum was associated with groundnut in Gambia.

Most *Striga*-infested areas already have high levels of the parasite seeds in the soil. The adoption of control measures that aim to reduce the level of this *Striga* seed inoculum has to be encouraged. The potentials of cereal-legume rotation and intercropping to manage *Striga* infestation in cereals has been demonstrated under controlled, researcher-managed conditions. It is therefore necessary to demonstrate that these technologies work efficiently under farmer-managed conditions and are indeed appropriate for African farmers (FISHER, 1999). The present study is a long-term farmer-managed *Striga* control project comparing short- and long-term rotation of a *Striga*-resistant maize with soybean and cowpea. Controls were maize intercropped with soybean and continuous cropping with *Striga*-resistant maize.

2 Materials and Methods

The trials were established with farmer management on 12 farmers' fields selected in two neighboring villages in Kaduna State, (northern Nigeria) in 2001, 2002, and 2003. The fields are located in the northern Guinea savanna zone, which is characterized by a sub-humid climate with monmodal rainfall of 900-1200mm, which extends over an annual growing period of 150-180 days. Rainfall was 1322 mm in 2001, 1007 mm 2002, and 1135 mm in 2003. The main characteristics of the soils are presented in Table 1.

Table 1: Soil properties in the trial sites.

Property	*Ungwan Shamaki*	*Tasha Kaya*
pH ($CaCl_2$)	5.1	4.9
Total N (g kg^{-1})	0.2	0.08
Organic Carbon (g kg^{-1})	4.8	5.0
Bray 1-P (mg kg^{-1})	3.75	5.1

All trials were conducted on sites infested with *Striga hermonthica* and simultaneously served as demonstration plots for participating farmers. The treatments were as follows:

(i) Cowpea-maize intercrop,
(ii) one year of soybean followed by two years of maize,
(iii) one year of cowpea followed by two years of maize,
(iv) two years of soybean followed by one year of maize,
(v) two years cowpea followed by one year of maize and
(vi) continuous sole cropped maize as control.

The maize used was an improved *Striga*-tolerant open-pollinated maize variety (Acr. 97TZL Comp1-W). The soybean was an *Alectra*-tolerant and high N-fixing variety (TXG1448-2E) while the cowpea used in the intercrop was a *Striga*-tolerant early-maturing variety (IT93K452-1). The two legume varieties have been found to cause suicidal germination of *Striga* in screen house experiments (BERNER *et al.*, 1996). The experimental arrangement in each farmer's field is illustrated in Table 2.

Table 2: Arrangement of treatments on farmers' fields.

Location	*Year 1*	*Year 2*	*Year 3*
1	Resistant Maize	Resistant Maize	Resistant Maize
2	Soybean	Resistant Maize	Resistant Maize
3	Soybean	Soybean	Resistant Maize
4	Cowpea	Resistant Maize	Resistant Maize
5	Cowpea	Cowpea	Resistant Maize
6	Cowpea-maize intercrop	Cowpea-maize intercrop	Cowpea-maize intercrop

The trials were successfully established on eight farmers' fields at Ungwa Shamaki and four at Tashan Kaya. The villages were less than 5 km from each other and had similar soil and climatic conditions. Each farm with the six plots constituted a replicate. The gross plot size was 150m^2 and the net size was 135m^2. In 2001, each crop was planted on ridges as a sole crop except for the maize-cowpea intercrop treatment. Maize was sown at 3 seeds per hill at a spacing of 75 $\times$ 50 cm. At two weeks after sowing (WAS), maize was thinned to two plants per stand. Soybean was drilled at a spacing of 5 cm on ridges with 75 cm interspace. In the sole cowpea variant, two seeds were planted on ridges at a spacing of $\times$ without thinning but in the intercrop variant one stand of cowpea was planted between two maize stands. In 2002 and 2003, the same operations were performed as in 2001.

All crops were hoe weeded at 3 and 6 WAS followed by a careful hand-pulling of other annual weeds except *Striga*.

Fertilizer was applied at the recommended rate of 100 kg N/ha, 50kg P/ha and 50kg K/ha using NPK and urea. The nitrogen fertilizer was split-applied at 3 and 6 WAS. Fertilizer was applied to soybean and cowpeas at the rate of 20kg N/ha, 40kg P/ha, and 20kg K/ha at 2 WAS using NPK (20:10:10), single superphosphate and muriate of potash. The cowpeas were sprayed with Cyper Plus (250 g Cypermetrin/ha) at the rate of 1 l/ha at flower bud initiation and Benlate (3 g Benomyl/ha) was applied at 0.4 kg/ha during podding to control fungal diseases and insect pests.

Data collected included maize stand count, *Striga* shoot count (infestation), number of maize plants infested (incidence), host damage severity on a scale of 1-9 (where 9 $\widehat{=}$ completely dead plants), and grain yield of maize, soybean and cowpea. Crop value in the systems was calculated using the Naira (₦, Nigerian currency) prices for the component commodity crops. The data were subjected to analysis of variance and treatment means were compared using Duncan Multiple Range Test (DMRT). Data on yield of soybean are not reported in this paper since they are not harvested from the same plot as maize.

Table 3: Effects of sole and intercropping on plant population, *Striga* infestation, crop damage severity and grain yield of maize on farmers' fields in northern Nigeria (2001).

Cropping system	*Maize** *(plants/ha)*	*Striga** *(no./ha)*	*Infested maize** *(plants/ha)*	*Crop damage*† *severity (1-9)*	*Maize grain yield (kg/ha)*	*Maize value (₦)*‡	*Cowpea seed yield (kg/ha)*	*Cowpea value (₦)*§	*Total value (₦)*
Sole maize	21,013^{a}	1158.3^{a}	414.6^{a}	2.33^{a}	810.42^{a}	16,208	-	-	16,208
Maize-cowpea intercrop	17,371^{b}	433.3^{b}	295.8^{b}	2.58^{b}	613.54^{a}	12,270	306	9,180	21,450

* at 12 WAS (weeks after sowing)
† Crop damage severity using a scale of 1 - 9, where 1 ≘ healthy plants and 9 ≘ completely dead plants
‡ at ₦20/kg, § at ₦30/kg

Table 4: Effects of previous crops on plant population, *Striga* infestation, crop damage severity, and grain yield of maize on farmers' fields in northern Nigeria in the second year (2002).

Cropping system[‡]	*Maize** *(plants/ha)*	*Striga** *(no./ha)*	*Infested maize** *(plants/ha)*	*Crop damage*[†] *severity (1-9)*	*Maize grain yield (kg/ha)*	*Maize value (₦)*[§]	*Cowpea seed yield (kg/ha)*	*Cowpea value (₦)*[¶]	*Total value (₦)*
M–M	$21{,}433^{c}$	1191.7^{a}	343.8^{a}	4.08^{a}	1147.6^{b}	22, 952	–	–	22,952
S–M	$22{,}954^{ab}$	772.9^{b}	272.9^{b}	3.50^{b}	1468.4^{a}	29,360	–	–	29,360
C–M	$23{,}988^{a}$	1025.0^{ab}	431.3^{ab}	3.67^{b}	1384.0^{a}	27,680	–	–	27,680
Maize-cowpea intercrop	$22{,}513^{bc}$	375.0^{b}	202.1^{b}	4.17^{a}	782.5^{c}	–	697	27,880	43,530

* at 12 WAS (weeks after sowing)
† Crop damage severity using a scale of 1 - 9, where 1 ≘ healthy plants and 9 ≘ completely dead plants
‡ M–M ≘ sole maize, S–M ≘ maize after soybean, C–M ≘ maize after cowpea
§ at ₦20/kg, ¶ at ₦30/kg
Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

Table 5: Effects of previous crops on plant population, *Striga* infestation, crop damage severity, and grain yield of maize on farmers' fields in northern Nigeria in the third year (2003).

Cropping system	*Maize* (plants/ha)*	*Striga* (no./ha)*	*Infested maize* (plants/ha)*	*Crop damage† severity (1-9)*	*Maize grain yield (kg/ha)*	*Maize value (₦)‡*	*Cowpea seed yield (kg/ha)*	*Cowpea value (₦)§*	*Total value (₦)*
M–M–M	23,022^{b}	489^{a}	273^{a}	4.5^{a}	1167^{c}	23,400	–	–	23,400
S–M–M	23,296^{a}	291^{ab}	173^{ab}	3.8^{ab}	1569^{bc}	31,380	–	–	31,380
C–M–M	23,216^{a}	293^{ab}	178^{ab}	4.1^{a}	1398^{c}	27,960	–	–	27,960
S–S–M	23,263^{a}	111^{b}	98^{b}	3.3^{b}	2185^{a}	43,700	–	–	43,700
C–C–M	23,076^{b}	121	^{b} 86^{b}	3.7^{ab}	1939^{ab}	38,780	–	–	38,780
M–C intercrop	22,611^{c}	94^{b}	73^{b}	4.1^{a}	1400^{c}	28,000	680	27,200	55, 200

* at 12 WAS (weeks after sowing)
† Crop damage severity using a scale of 1 - 9, where 1 ≘ healthy plants and 9 ≘ completely dead plants
‡ M–M–M ≘ maize–maize–maize, S–M–M ≘ soybean–maize–maize, C–M–M ≘ cowpea–maize–maize, S–S–M ≘ soybean–soybean–maize, C–C–M ≘ cowpea–cowpea–maize
§ at ₦20/kg, ¶ at ₦30/kg
Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

3 Results

3.1 Sole and intercropping effects on Striga and maize in the first year

In 2001, the sole-cropped and intercropped maize exhibited similar low levels of crop damage severity. The sole maize had better plant establishment than the intercropped maize although these were planted at the same density. *Striga* infestation and incidence were lower when maize was intercropped with cowpea than when planted sole. However, maize grain yield was 32% higher (not significant different at 5%) when planted solecompared to intercropped with cowpea (Table 3).

3.2 Effects of one-year rotation on Striga infestation and maize grain yield

In 2002, plant population at harvest was generally lower than optimal for all treatments. Maize grown after one year of soybean and cowpea had a significantly higher plant population than the intercropped and continuously cropped maize. The number of emerged *Striga* was significantly higher in continuously cropped maize compared to maize after one year of soybean and cowpea intercropped maize (Table 4). *Striga* infestation was 70% lower in intercropped maize, 54% lower in maize after soybean, and 16% lower in maize after cowpea compared to continuously cropped maize. Crop damage severity was similar and higher in continuously cropped and intercropped maize than in maize after soybean and cowpea.

Maize after one year of soybean and maize after one year of cowpea had significantly higher grain yield than the intercropped and continuously cropped maize. Maize grain yield was 28% higher after one year of soybean and 21% higher after one year of cowpea than in the continuously cropped maize. Continuously cropped maize recorded 47% higher grain yield than the intercropped maize (Table 4). However, intercropping maize with cowpea produced 90% more crop value than sole cropped maize.

3.3 Effects of two-year rotation on Striga infestation and maize grain yield

Plant population at harvest was generally lower than the recommended practice for all treatments in 2003 (Table 5). The number of emerged *Striga*/ha was significantly higher in continuously cropped maize than in maize grown after two years of soybean or cowpea and intercropped maize. *Striga* number was 81% lower in intercropped maize, 77% lower in maize after two years soybean, and 75% lower in maize after two years of cowpea than in continuously cropped maize. *Striga* number/ha in maize after two years of soybean was 62% lower than in maize after one year of soybean. *Striga* number/ha in maize after two years of cowpea was 59% lower than in maize after one year of cowpea. *Striga* number in maize continuously cropped for two years after one year of soybean or cowpea was 40% lower than in maize continuously cropped for three years without rotation with legumes. Continuously cropping the *Striga*-resistant/tolerant maize for three years reduced number of emerged *Striga*/ha by 57%. Crop damage severity in maize after two years of soybean was significantly lower than in all other treatments. Cropped damage severity in continuously cropped and intercropped maize increased with years of cultivation. However, crop damage scores were generally low for all treatments.

Maize grain yield after two years of soybean was 87% higher than maize continuously cropped for three years. Maize grain yield after two years of cowpea was 67% higher than the continuously cropped maize. Maize grain yield in maize-cowpea intercrop was 20% higher than the continuously cropped maize. Seed yield of cowpea in the intercropped was relatively lower than that normally obtained for sole crop of the cowpea variety used in this trial. Continuous cropping of maize for two years after one year of soybean and cowpea recorded grain yield 34 and 19% higher than maize continuously cropped for two years respectively. Maize grain yield after two years of soybean was 32.8% higher than maize grain yield after one year of soybean. Maize grain yield after two years of cowpea was 28.6% higher than maize after one year of cowpea. Intercropping maize with cowpea on the same plot for three years produced 136% more crop value than sole cropped maize.

3.4 Effects of previous crops on total soil nitrogen and available phosphorus

The effect of previous crops on total soil N at 0 to 10 cm depth is summarized in Table 6. Total N in the previous soybean and cowpea plots, and the intercropped maize plots was higher than in the continuously cropped maize plots. Mean total N in the plots previously cropped to legumes or intercropped with cowpea was 20% higher than the continuously cropped maize. There were no significant differences between previous soybean, cowpea, and maize-cowpea intercrops. Previous soybean and cowpea contributed similar amounts of N to the soil at all locations. Available P values in the soil were higher in plots previously cropped to soybean, cowpea or maize-cowpea intercropped than in continuously cropped maize. Average P values in plots after two years of soybean or cowpea were 70% higher than in continuously cropped maize. After one year of soybean or cowpea, average P values were 20% more than in continuously maize. P availability in maize-cowpea intercropped was not significantly different from two years of cowpea or soybean.

Table 6: Effect of previous crop on total soil nitrogen and available phosphorus before maize planting in 2003.

Treatments	*total* N *(g/kg)*	*avail.* P *(mg/kg)*
2 years sole maize	0.68	4.86
1 year soybean followed 1 year maize	0.79	4.99
2 years sole soybean	0.81	9.38
1 year cowpea followed by 1 year maize	0.81	6.91
2 years sole cowpea	0.83	7.18
2 years maize/cowpea intercrop	0.84	7.69
Mean	0.79	6.84
S.E.	0.02	0.79

4 Discussion

The trials demonstrated the potential of appropriate soybean and cowpea cultivars to reduce *Striga* parasitism in subsequent maize. It also demonstrated the potential of maize-cowpea intercrops to control *Striga*. The two legume cultivars used were able to reduce *Striga* parasitism in the rotation systems. Intercropping maize with cowpea reduced emerged *Striga* density. This reduction may be due to shading effects from the cowpea canopy. CARSON (1989) reported a positive relationship between soil temperatures under groundnut intercropped with sorghum and emerged *Striga* density. He found that the soil temperature at a depth of 10 cm at 6 to 7 weeks after sorghum emergence was about 2°C lower in sorghum rows and that *Striga* density at sorghum harvest was reduced by 60 to 70% in the treatment with sorghum and groundnut in the same row. CARSKY *et al.* (1994) reported that the number of mature capsule-bearing *Striga* plants was low when the cowpea ground cover was high in a sorghum-cowpea intercrop. This suggests that any spatial arrangement that increases cowpea ground cover at the base of maize or sorghum can reduce the density of mature *Striga*. CARSKY *et al.* (1994) therefore, concluded that in the long term, this might reduce the density of *Striga* seed, provided no importation of *Striga* seed to the field were allowed. They also found no significant reduction in sorghum yield by intercropping sorghum with cowpea. In the present study, intercropping cowpea with maize reduced maize yield by 47% despite the reduction in the number of emerged *Striga*. This may be due to a competition effect from the cowpea crop on the maize crop. This corroborates the findings of KUREH *et al.* (2000) and KUCHINDA *et al.* (2003). When maize and cowpea are planted at the same time in intercropping systems, the fast growing and profuse branching cowpea competes with the maize crop for light, water, and nutrients. This slows than maize growth considerably thereby reducing yield. Maize and sorghum appear to have different reactions to competition effects from other crops in intercropping systems. Maize has a shorter maturity period than sorghum. Hence, sorghum may overcome the effects of intercropping long after the cowpea has been harvested. Intercropping maize with cowpea is a good agronomic practice for *Striga* management due to reduced *Striga* infestation and high total crop value. KUREH *et al.* (2000) similarly reported better *Striga* management and increased crop value when soybean is intercropped with maize.

Despite the considerable reduction in maize yield when intercropped with cowpea, this system recorded higher crop value than the sole cropped maize in both rotation with legumes or when continuously cropped. Grain yield reduction of maize when intercropped with cowpea was compensated for by the higher cash value of cowpea in the intercropping system. Because of this reason, intercropping may continue to be one of the options for *Striga* control.

Several studies have shown a significant reduction in *Striga* attack by adopting cropping systems that include intercropping and rotations (CARSKY *et al.*, 1994, 2000; SCHULZ *et al.*, 2003; KUCHINDA *et al.*, 2003). Several other mechanisms can be suggested to explain the reduction of *Striga* when maize is intercropped or rotated with legume trap crops. In addition to shading out *Striga* in intercropping systems, the cowpea or soybean has been shown to stimulate the germination of *Striga* without acting as hosts

(Carsky *et al.*, 1994; Berner *et al.*, 1996; Carsky *et al.*, 2000; Kureh *et al.*, 2000; Kuchinda *et al.*, 2003). In this study, the extent of reduction in *Striga* infestation was dependent on the type of legume and number of years soybean or cowpea were cultivated before maize cultivation. For example, *Striga* infestation was 54% lower after one year of soybean and 16% lower after one year of cowpea. However, in the second year, there was higher level of reductions when the legumes were cultivated for two years before maize was cultivated. *Striga* infestation in maize was reduced by 77% after two years of soybean and 75% after two years of cowpea. In addition, maize grain yield increased by 87% after two years of soybean and 66% after two years of cowpea. These indicate the ability of these grain legumes to reduce *Striga* infestation and increase grain yield. On heavily infested *Striga* fields, more frequent cultivation of grain legumes before the introduction of cereals may be necessary.

Striga germination may also be suppressed by the nitrogen fixed by the legumes. However, this does not appear to be likely because the legumes do not release much nitrogen into the soil during their growth (van der Heide *et al.*, 1985; Carsky *et al.*, 1994; Sanginga *et al.*, 2002). Usually large amounts of nitrogen are required to reduce *Striga* density (Mumera and Below, 1993). However, improved growth and vigor due to N may help the maize crop to overcome *Striga* attacks. Although there were significant reductions in *Striga* infestation and maize yield loss due to *Striga*, *Striga* infestation and damage ratings in the continuously cropped maize was lower than that reported for *Striga*-susceptible maize in the savanna (A. Menkir, personal communication). This is because the maize variety used was *Striga*-resistant/tolerant. It is presently the most resistant maize against *Striga* in the West African savanna. Its continuous cultivation may lead to reduction in the *Striga* seed bank.

Although the above benefits of legume rotation in *Striga* control may be unrelated to N supply, our data show that legume-maize rotation increased N supply to subsequent maize. Although all treatments received equal amounts of fertilizer N (100 kg N/ha), total N in previous legume plots was more than in continuous maize plots. This additional N supply coupled with other rotational effects may have increased the yield of subsequent maize. Carsky *et al.* (1997) established N supply as the major influence of soybean on subsequent maize and found a reduction in maize yield response to inorganic N following soybean. The increases in N supply in previous cowpea and soybean treatments and yield of subsequent maize was probably due to additional N fixed and left in the soil for the subsequent maize crop. Sanginga *et al.* (2002) reported a nodulating soybean to fix about 103 kg N/ha of its total N with an estimated net N balance input from fixation following grain harvest of 43 kg N/ha. They also reported that maize growing after this soybean had 1.2 to 2.3-fold increase in yield compared to the maize control. In the present study, N contents of roots and litter of the previous soybean and maize crops were not determined, so the two effects could not be quantified.

5 Conclusion

It can be concluded from our findings that:

(1) Continuous cultivation of sole maize will increase *Striga* infestation. However, if the maize grown is resistant to *Striga*, there may be some reduction in field infestation due to depletion of *Striga* seed bank.

(2) Rotation of cereals and grain legumes such as soybean and cowpea can reduce *Striga* infestation and increase grain yield. The reduction of *Striga* infestation and maize yield increases will be higher if the legumes are cultivated for over one cropping seasons before maize is introduced.

(3) Although, maize-cowpea intercropping reduced maize grain yield due to competition effects, the higher crop value of cowpea component makes the system profitable and farmers should be encouraged to continue practicing it.

Acknowledgements
The authors thank the Cereal Programme staff of IAR/ABU for technical support and West African Maize Network (WECAMAN) for Research Grant.

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Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 107, No. 1, 2006, pages 55–66

Wirkungen eines polymeren Bodenverbesserers auf die Ertragsbildung von Hirse unter ariden Bedingungen

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Zusammenfassung

Wasser ist in (semi)ariden Gebieten der entscheidende begrenzende Faktor in der Pflanzenproduktion. Unter dem Aspekt einer erhoehten Wasserspeicherung wurde die Wirkung einer Polymer-Gabe von 0 bzw. 0.3 % (G/G) zu drei Böden (leicht/mittel/schwer) bei drei Bewässerungsfrequenzen (4-, 8-, und 12-tägig) auf die Ertragsbildung von Hirse (*Panicum antidotale* Retz), die Wasserspeicherung und N-Auswaschung im Freiland (nordwestlich von Teheran) geprüft.

Vierzig Tage (d) nach Versuchsbeginn sank die Überlebensrate der Pflanzen, insbesondere auf leichtem Boden und bei geringer Bewässerungsfrequenz progressiv. Polymer-Zusatz und eine erhöhte Bewaesserungsfrequenz zeitigten bei allen Pflanzenmerkmalen klare positive Wirkungen, wobei z. T. deutliche Interaktionen, auch mit den Boeden bestanden. Auf allen Böden, insbesondere aber auf mittlerem Boden, welcher die Rispen- und Biomassebildung begünstigte, war der Effekt des Polymerzusatzes bei geringer bzw. mittlerer Bewässerungsfrequenz am stärksten ausgepraegt. Die Wechselwirkungen zwischen den Versuchsfaktoren werden vor dem Hintergrund einer durch Polymerzusatz erhoehten Wasserspeicherung und verminderten N-Auswaschung diskutiert.

Stichwörter: Polymer, Wasserspeicherung, Bewässerungsfrequenz, Bodenarten, Ertragsbildung von Hirse, Uberlebensrate, N-Auswaschung

1 Einleitung

Wasser stellt ein Hauptproblemfaktor in der Pflanzenproduktion arider und semiarider Regionen dar. Nicht nur die natürliche Wasserknappheit begrenzt die Standortproduktivität, sondern auch ungünstige physikalische Bodeneigenschaften, wie geringe Infiltration, sowie Wasserspeicherung und -nachlieferung. Neben der Anwendung von Gründüngung, Mulchen oder anderer organischer Dünger, die zur Milderung dieser Probleme beitragen können, ist in den letzten Jahren auch der Einsatz von polymeren Bodenverbesserern getestet worden. Hierzu zählen z.B. Perlit, Igeta, Hydroplus und andere Superabsorbenten bzw. Polymere. Diese Mittel können bei Kontakt mit Was-

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ser das 300 bis 500-fache ihres Volumens an Wasser absorbieren und es wieder an die Pflanzen abgeben. Neben dieser Wasserabsorption, die zu einer besseren Pflanzen- und Wurzelentwicklung führen kann, ist auch eine verminderte Nährstoffauswaschung aus dem Boden durch Polymere zu erwarten, wobei die Wirksamkeit im Boden mit bis ca. 5 Jahren angegeben wird (*Super AB, A-100*, Iran Polymer Institute). Polymere Bodenverbesserer können bei Neuanpflanzungen von Baumkulturen auf leichteren Böden trockener Klimata positive Effekte erzielen, wie Dosiseffekte von Polymerzusätzen zum Boden auf die Überlebensrate von Kiefernsämlingen (*Pinus halepensis*) in Versuchen von HÜTTERMANN *et al.* (1997) belegen. In Versuchen mit *Populus euphratica* auf salzhaltigem Boden (Hüttermann et al. 1997) liessen Polymer-Behandlungen mit 0 % bis 0.6 % nach 7 und nach 60 Tagen ebenfalls abgestufte, deutliche Verbesserungen von Wachstum und Überlebensrate erkennen.

Aus anderen Bewässerungsversuchen von HÜTTERMANN *et al.* (1999) auf leichten Wüstenböden geht hervor, dass die durch Polymere gesteigerte Wasserspeicherung einen entscheidenden Einfluss auf das Überleben der Pflanzen ausübten. Darüber hinaus konnte in diesen Versuchen, wie auch in denen von DEHGAN *et al.* (1994), eine erhöhte Wurzelmasse bei Polymerzugaben beobachtet werden. In einem weiteren Bericht über Polymerversuche in Südafrika wird mitgeteilt, dass durch die Verwendung von Polymeren im Boden nicht nur die Sterblichkeitsrate von Eukalyptuspflanzen deutlich reduziert wurde, sondern auch die Bewässerungskosten abnahmen (ANONYMOUS, 1998).

Ziel dieser Untersuchung war es, zu prüfen, inwieweit auch an annuellen Nutzpflanzen unter den ariden Bedingungen des Irans positive Wirkungen von Polymerzugaben nachgewiesen werden können. Darüber hinaus sollten mögliche Wechselwirkungen mit Bewässerungsmassnahmen bzw. mit unterschiedlichen Wasserspeicherkapazitäten von Böden untersucht werden. Als annuelle Pflanze wurde hier Futterhirse (*Panicum antidotale* Retz.) ausgewählt, weil diese Pflanze neben Viehfutter auch als Schutz gegen Winderosionen in Trocken- bzw. Wüstengebieten eingesetzt werden kann.

2 Material und Methoden

Die Untersuchungen wurden in einem Gefässversuch im Freiland während des Jahres 2000 am Forschungsinstitut für Wald und Weidewirtschaft (16 km nord-östlich von Teheran, 1300 m ü. NN) durchgeführt. Die mittleren jährlichen Niederschläge betragen dort ca. 230 mm mit Schwerpunkten im Frühjahr und im Spätherbst, so dass während der Versuchsmonate im Sommer weniger als 10 mm Regen fielen. Während des Versuchszeitraums betrug die monatliche Verdunstung ca. 170 mm und die mittleren Temperaturen lagen bei 21°C. Das Saatgut der Futterhirse (*Panicum antidotale* Retz.) wurde aus der Genbank des Forschungsinstituts (für Wald- und Weidewirtschaft) bezogen und zuvor auf seine Keimfähigkeit geprüft. Es wurden vier Körner pro Gefäss ausgesät und später auf eine Pflanze pro Topf ausgedünnt. Die Gefässe wurden jeweils mit 4 kg Boden unterschiedlicher Herkunft und Art (leicht, mittel und schwer, s. Tab. 1) befüllt. Den Böden wurde eine Dosis von 0 bzw. 0,3 % (G/G) des Polymers *Super AB, A-100* (Iran Polymer Institute) zugesetzt, welches den Verhältnissen in anderen Untersuchungen entsprach (WANG und GREGG, 1990; BOWMAN *et al.*, 1990; DEHGAN *et al.*, 1994; HÜTTER-

MANN *et al.*, 1997, 1999). Das verwendete Polymer bestand aus Polyacrylsäure mit einer Körnung von 0,05 - 0,15 mm, einer Dichte von 1,4 - 1,5 g/cm^3 und hatte einen pH-Wert von 6 - 7 im wassergesättigten Zustand, welcher bei 203 g/g Polymer erreicht war. Die Bewässerung wurde mit 3 unterschiedlichen Frequenzen, alle 4, 8 oder 12 Tage vorgenommen, wobei zu jedem Bewässerungstermin den Gefässen entsprechend des Gewichts Wasser bis zum leichten Überschreiten der Feldkapazität zugegeben wurde.

Der Versuch war als split-split-plot design angelegt mit 3 Bewässerungsfrequenzen (3 main plots), die jeweils die 3 Bodenarten (3 split plots) beinhalteten, die wiederum jeweils in den unbehandelten und polymer-behandelten Boden (2 subsplit plots) unterteilt waren. Der Versuch wurde mit 4 Wiederholungen durchgeführt.

Die Düngermengen fur N-P-K entsprachen den Empfehlungen von FINCK (1992) (berechnet über 80 000 Pflanzen/ha). Eine P- und K-Düngung (35 kg P/ha, 200 kg K /ha) wurde in Form von Triplesuperphosphat und Kaliumsulfat vorgenommen und dem Boden vor der Saat beigemischt. Die Stickstoffdüngung wurde mit ca. 100 kg/ha N dem Boden als wässrige Lösung in Form von Ammoniumnitrat zugeführt..Ein Viertel der N -Menge wurde im Sämlingsstadium, der Rest zur Blüte verabreicht. Die jeweils nach der N-Applikation erfolgenden 2 Bewässerungen waren derart bemessen, dass jeweils ca. 50-80 ml Sickerung erzeugt wurde, um den Einfluss des Bodenverbessers auf die potentielle N-Auswaschung ermitteln zu können.

Die Bodenkennwerte (Tab. 1) wurden im Labor des Research Institute of Forest & Rangelands i. W. nach Standardmethoden ermittelt (elektrische Leitfähigkeit und pH-Wert im Sättigungs-extrakt elektrometrisch, Stickstoff nach Kjeldahl mit Aufschluss nach ROWELL (1994), Carbonatgehalt nach SCHLICHTING *et al.* (1995), Phosphat nach Olsen gemäß SCHINNER *et al.* (1991), Kalium mit 1N Ammoniumacetat nach COTTENIE (1980), organischer Kohlenstoff nach Walkley und Black gemäß BARUAH und BARTHAKUR (1997), KAK mit Ammonium bzw. Natrium flammenphotometrisch und Korngrössenverteilung hydrometrisch).

Tabelle 1: Kenndaten der unbehandelten Versuchsböden.

Bodenart (% Ton/Schluff/Sand)	*pH*	*EC* [dS m^{-1}]	P [mg kg^{-1}]	K [cmol kg^{-1}]	*KAK* [%]	*WGS** [%]	N_t [%]	*OC* [%]	$CaCO_3$ [%]
leicht (2/2/96)	7.42	1.65	0.10	5.7	4.1	26.7	0.029	0.21	5.33
mittel (20/50/30)	7.78	3.51	0.25	27.1	8.2	35.9	0.045	0.40	6.67
schwer (30/38/32)	7.33	2.23	0.14	12.8	8.7	40.4	0.056	0.51	9.33

* Wassergehalt bei Sättigung [% G/G], ermittelt aus Gewicht im gesättigten und stark luftgetrockneten Boden.

An den Pflanzen wurde die phänologische Entwicklung (Feldaufgang, Schoss- und Blühbeginn, absolute Pflanzenanzahlen) jeweils an verschiedenen Tagen bonitiert und später die Überlebensrate regelmässig erfasst. Zur Varianzanalyse der Überlebensrate wurden die Daten zunächst nach der Formel $X = \sqrt{x + 0.5}$ transformiert und anschliessend analysiert, wobei x den Wert 0 für abgestorbene und 1 für lebende Pflanzen annehmen konnte. Bei der Probenahme einzelner Pflanzen wurde die Trockenmasse (105°C), die Rispenanzahl und die Pflanzenhöhe ermittelt. Das Datenmaterial wurde einer Varianzanalyse unterzogen und bei Vorliegen von signifikanten Effekten wurden Mittelwertsvergleiche mittels des Duncan-Tests durchgeführt. Die Auswertung erfolgte mit dem Statistikprogramm MSTAT.

3 Ergebnisse

Die phänologische Entwicklung der Futterhirse war gekennzeichnet durch Aufgang am 7.-9. Tag nach der Saat (TnS), Schossbeginn zwischen dem 31.-38. TnS und Blühbeginn zwischen dem 52.-55. TnS. Die drei Versuchsfaktoren zeitigten bei allen fünf Pflanzenmerkmalen (Tab. 2) signifikante Hauptwirkungen, aber auch Wechselwirkungen, insbesondere zwischen der Bewässerung (A) und dem Boden (B). Bezüglich der Hauptwirkungen (Tab. 3) erwies sich der mittlere Boden generell als das günstigste Substrat und eine Verringerung der Bewässerungsfrequenz senkte sowohl Überlebensrate, die Pflanzenhöhe, Rispenanzahl und Trockenmasse der Hirse stufenweise; hierbei war die Reduktion jeweils auf dem leichten Boden relativ am stärksten ausgeprägt. Ein positiver Effekt des polymeren Bodenverbesserers auf die Überlebensrate der Hirse (Abb. 1) prägte sich zunehmend ab dem 35 TnS aus, und erhöhte die Rate zur Reife absolut um 10 %, was im wesentlichen auf der Wirkung bei leichtem Boden mit 4- und 8-tägiger Bewässerung und bei mittlerem Boden bei 12-tägiger Bewässerung beruhte (vergl. Tab. 3).

Tabelle 2: Varianzanalysen zum Einfluss der Versuchsfaktoren Bewässerung (A), Boden (B) und Polymerzusatz (C) auf verschiedene Merkmale.

		F-Werte				
Quelle	*Freiheitsgrade*	*Überlebensrate*†	*Rispenzahl*	*Pflanzenhöhe*	*Trockenmasse*	N *im Dränwasser*
A	2 (1)‡	10.5**	18.3***	13.8***	47.6**	32.8**
B	2	33.4**	72.7***	37.1***	75.1**	14.3**
AB	4	7.0**	5.8**	1.4^{ns}	4.9**	5.9*
Error	27 (6)‡	–	–	–	–	–
C	1	4.8*	15.1***	13.1**	67.3**	10.2*
AC	2	0.3^{ns}	0.6^{ns}	0.01^{ns}	0.5^{ns}	0.6^{ns}
BC	2	2.1^{ns}	1.6^{ns}	1.0^{ns}	3.5*	0.9^{ns}
ABC	4	1.7^{ns}	4.4**	3.6*	3.3*	0.1^{ns}
Error	27 (6)‡	–	–	–	–	–
Total	71 (23)‡	–	–	–	–	–

† Freiheitsgrade ( ) für N im Dränwasser; ‡ transformierte Daten
*/**: signifikant bei p = 0.05 bzw. 0.01, ^{ns}: not significant

Das Zusammenwirken der drei Versuchsfaktoren auf die wichtigen Ertragsmerkmale Rispenanzahl und Trockenmasse (Abb. 2 und 3) war sehr ähnlich, wobei ein positiver Polymer-Effekt sich praktisch auf allen Boden×Bewässerung-Kombinationen abzeichne-

Tabelle 3: Haupt- und Wechselwirkungen[1] von Bewässerung (A) und Boden (B) auf die diversen Merkmale der Rispenhirse am Versuchsende.

Merkmal	*Boden*	*Bewässerungsfrequenz* 4-tätig	8-tägig	12-tägig	*Boden (B)*
Überlebensrate [%][2]	leicht	88.8 ^{a}	55.0 ^{b}	10.0 ^{c}	51.3$^{\beta}$
	mittel	100.0 ^{a}	100.0 ^{a}	88.8 ^{a}	96.3$^{\alpha}$
	schwer	100.0 ^{a}	100.0 ^{a}	100.0 ^{a}	100.0$^{\alpha}$
	Bewässerung (A)	96.3$^{\alpha}$	85.0$^{\alpha}$	66.3$^{\beta}$	–
Pflanzenhöhe [cm]	leicht	Keine signifikante Wechselwirkung (ns) zwischen A×B			17.2$^{\beta}$
	mittel				46.6$^{\alpha}$
	schwer				54.3$^{\alpha}$
	Bewässerung (A)	52.5$^{\alpha}$	36.7$^{\beta}$	29.0$^{\beta}$	–
Rispenanzahl je Pflanze	leicht	1.1 ^{d}	0.3 ^{e}	0.0 ^{e}	0.5$^{\gamma}$
	mittel	9.3 ^{a}	5.4 ^{b}	3.3 ^{c}	6.0$^{\alpha}$
	schwer	2.6 ^{cd}	1.4 ^{cde}	1.4 ^{cde}	1.8$^{\beta}$
	Bewässerung (A)	4.3$^{\alpha}$	2.4$^{\beta}$	1.6$^{\beta}$	–
Trockenmasse je Pflanze [g]	leicht	2.20 ^{d}	0.68 ^{e}	0.00 ^{e}	0.96$^{\gamma}$
	mittel	6.75 ^{a}	3.74 ^{b}	2.53 ^{cd}	4.34$^{\alpha}$
	schwer	3.48 ^{bc}	2.35 ^{d}	2.09 ^{d}	2.64$^{\beta}$
	Bewässerung (A)	4.14$^{\alpha}$	2.25$^{\beta}$	1.54$^{\gamma}$	–

[1]: unterschiedliche Buchstaben zeigen signifikante Hauptwirkungen A bzw. B (α, β, γ) bzw. Wechselwirkungen A × B ($a - e$) an
[2]: transformierte Daten

te. Ausnahme bildeten die Kombination L12, wo alle Pflanzen abgestorben waren, und M4, bei der ohne Polymergaben höchste Rispenanzahlen und Trockenmassen erreicht wurden. Signifikant war der Polymer-Effekt bei den Kombinationen (S8), S4, M12 und M8, bei welchen halbwegs passable Wachstumsbedingungen (s. u.) auch ohne Polymergaben noch eine mäßige Ausprägung zu liessen. Dies zeigt sich auch an der zunehmenden Polymer-Wirksamkeit von leichten, über den schweren, zum mittleren Boden (Tab. 4).

Effekte der polymeren Bodenverbesserer auf die Pflanzen könnten unmittelbar über die erhöhte Wasserspeicherfähigkeit der Böden, aber auch indirekt über eine verminderte Nährstoffauswaschung bei überschüssigem Regen wirksam werden. Deshalb wurden die Feldkapazität und N-Menge in Sickerwasser untersucht. Der Wassergehalt bei Feldka-

Abbildung 1: Wirkung des polymeren Bodenverbesserers auf die Überlebensrate von Hirse.

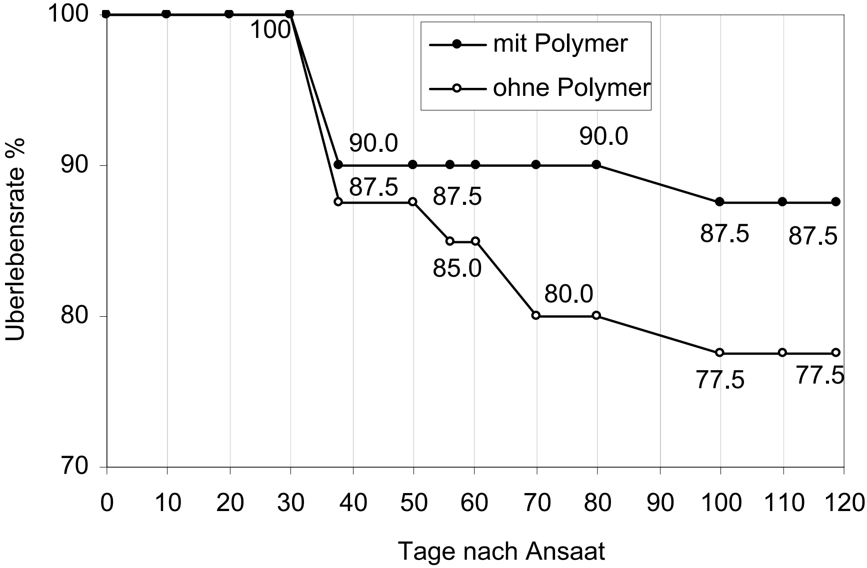

Abbildung 2: Wechselwirkungen von Polymerzusatz, Bewässerung und Boden auf die Rispenanzahl von Hirsepflanzen am Versuchsende. (Bewässerung: 12/8/4 =12-, 8- und 4-tägig; Boden: L=leicht, M=mittel, S=schwer; gleiche Buchstaben bedeuten keinen signifikanten Unterschied bei $p<0.05$).

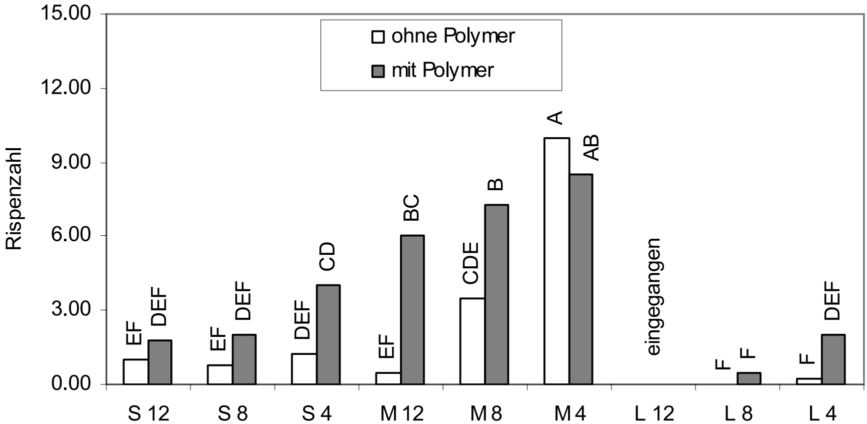

Abbildung 3: Wechselwirkungen von Polymerzusatz, Bewässerung und Boden auf die Trockenmassenbildung (g) von Hirsepflanzen am Versuchsende. (Bewässerung: 12/8/4 =12-, 8- und 4-tägig; Boden: L=leicht, M=mittel, S=schwer; gleiche Buchstaben bedeuten keinen signifikanten Unterschied bei $p<0.05$)

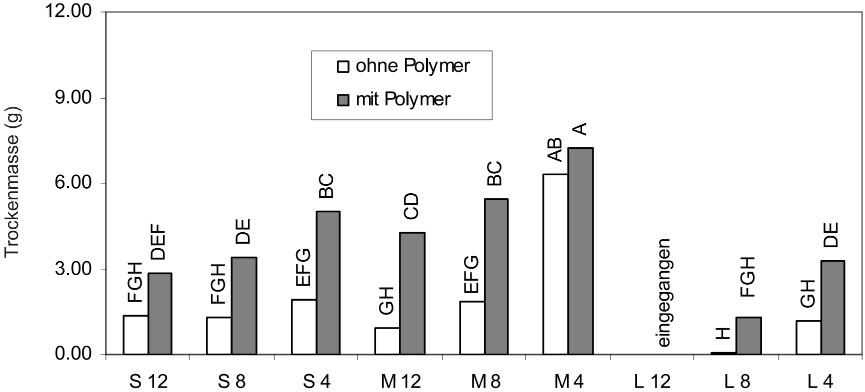

Tabelle 4: Wechselwirkung[1] zwischen Boden (B) und Polymerzusatz (C) auf die Trockenmasse von Hirse (g/Pflanze) am Versuchsende.

Bodenart	*Polymerzusatz*	
	ohne	*mit*
leicht	0.42 ^{d}	1.51 ^{c}
mittel	3.03 ^{b}	5.64 ^{a}
schwer	1.51 ^{c}	3.77 ^{b}

[1]: unterschiedliche Buchstaben zeigen signifikante Unterschiede zwischen Mittelwerten an.

pazität erhöhte sich durch die Polymere um 15 % (Tab. 5). Hinsichtlich der N-Menge im Sickerwasser (Tab. 6) ergaben sich als Hauptwirkungen eine Zunahme von der 4- zur 8-tägigen Bewässerung (A) bzw. von leichten zum schweren Boden (B) und eine Reduktion durch den Polymerzusatz (C). Zwischen Boden (B) und Bewässerung (A) bestand eine Wechselwirkung derart, dass die 4-tägige Bewässerung zwar generell niedrige N-Werte im Dränwasser der 3 Böden als die 8-tägige Bewässerung hervorrief, dies aber bei mittlerem Boden nur tendenziell erkennbar war.

Tabelle 5: Hauptwirkungen[1] von Polymerzusatz (C) und Boden (B) auf den Bodenwassergehalt bei Sättigung[2] [% G/G]

C Polymerzusatz		*B Boden*		
ohne	*mit*	*leicht*	*mittel*	*schwer*
34.3 $^{\alpha}$	49.1 $^{\beta}$	30.5 $^{\alpha}$	44.3 $^{\beta}$	50.5 $^{\gamma}$

[1]: B×C $n.s.$; unterschiedliche Buchstaben α, β, γ indizieren signifikante Mittelwertunterschiede.

[2]: aus Gewichten bei Wassersättigung und stark luftgetrockneten Böden ermittelt

Tabelle 6: Wechselwirkung zwischen Boden (B), Bewässerung (A)[1] bzw. Polymerzusatz (C) hinsichtlich den N-Konzentrationen im Dränwasser [mg N/l], an 2 Terminen nach N-Gabe ohne Berücksichtigung von 12-tägiger Beweasserung (s.Text).

Boden B	*Bewässerung A*		*Polymerzusatz C*		*Mittel B*
	4-tägig	*8-tägig*	*ohne*	*mit*	
leicht	295 ^{c}	766 ^{b}	Keine signifikante Wirkung B×C		531 $^{\beta}$
mittel	572 ^{bc}	664 ^{b}			618 $^{\beta}$
schwer	631 ^{b}	1348 ^{a}			990 $^{\alpha}$
Mittel A/C	500 ^{a}	926 ^{b}	884 $^{\alpha}$	542 $^{\beta}$	–

[1]: B×A signifikant; unterschiedliche Buchstaben zeigen Hauptwirkumgen A,B bzw. C (α, β, γ) bzw. Wechselwirkungen A×B ($a - e$)

4 Diskussion

Die phänologischen Beobachtungen zeigten, dass die Entwicklung der Futterhirse durch eine Zunahme der Bewässerungshäufigkeit bzw. durch die Polymerzugabe begünstigt war. Dies lässt sich wahrscheinlich auf bessere Wachstumsbedingungen zuruckführen und stimmt überein mit einer schnelleren phänologischen Entwicklung und einem besseren Wachstum verschiedener Gemüse- und Zierpflanzen in Folge von Polymerzugabe zum Boden in Untersuchungen von King *et al.* (1973); Ferrazza (1974); Bearce und McCollum (1977) (zitiert in Gehring und Lewis III (1980)). Verbesserte Wachstumsbedingungen spiegeln sich auch in den Überlebensraten wieder, welches an den Sämlingen von *Pinus halepensis* (Hüttermann *et al.*, 1997) durch Polymerzusatz von 0, 0,2 bzw. 0,4 % zum Boden bereits 17 TnS von 38 auf 50 bzw. 100 % festgestellt werden konnte. Auch der Anteil lebender Pflanzen von *Populus euphratica* konnte durch Zusatz von 0,6 % Polymer zu gips- und salzhaltigem Boden nach 60tägigem Wachstum von 46 auf 90 % gefördert werden (HÜTTERMANN *et al.*, 1997). Diese Ergebnisse stimmen mit der zwischen dem 40. und 100. TnS zunehmenden Steigerung der Überlebensrate von Futterhirse durch Polymere überein, welche allgemein von einer Zunahme der Rispenanzahl, Höhe und TM je Pflanze begleitet war. Grundsätzlich können diese Wirkungen an Futterhirse auf eine verbesserte Wasserspeicherung zurückgeführt werden, wie dies analog von GEHRING und LEWIS III (1980) und WEAVER *et al.* (1977) beschrieben wurde. Auch in anderen Arbeiten wird eine verbesserte Wasserspeicherung aufgrund von Polymeren als Ursache für ein verlängertes Überleben von Mais und Bohnen (BAKASS *et al.*, 2002) und für eine bessere Turgeszenz von Erdnuss (MOHANA RAJU *et al.*, 2002) bei knappen Wasserangebot angesehen.

Um die Wechselwirkungen zwischen Polymergabe und den Faktoren Boden bzw. Bewässerung zu bewerten, ist es notwendig zunächst die Wechselwirkung Boden-Bewässerung zu betrachten. Auf mittlerem Boden (und eingeschränkt auch bei leichtem) erhöhte eine zunehmende Bewässerungsfrequenz die Rispenanzahl und Trockenmasse von Futterhirse stufenweise, was auf Wassermangel als begrenzender Faktor für das Wachstum hinweist. Bei dem schweren Boden hatte die Bewässerung keinen bzw. nur einen schwachen Effekt. Hieraus ist zu schlussfolgern, dass Wassermangel zumindest nicht der einzige begrenzende Faktor war. Da der schwere Boden sich von mittleren nur durch einen höheren Ton- zulasten des Schluffgehaltes unterschied, dürfte dessen nutzbare Feldkapazität - trotz des höheren Wassergehalts bei Sättigung - aufgrund eines erheblich höheren Totwassergehaltes etwas geringer, aber besonders der Grobporenanteil deutlich geringer sein (SCHACHTSCHABEL *et al.*, 1989). Letzteres dürfte eine schlechte Belüftung bedingen und neben geringerer P- und K-Verfügbarkeit Ursache für eine verminderte Rispen- und TM-Bildung bei Futterhirse auf dem schweren im Vergleich zum mittleren Boden sein. Insofern ist davon auszugehen, dass bei höherer Bewässerungsfreqünz die schlechte Belüftung des schweren Bodens durch Verschlämmung der Bodenoberfläche und Stauwasser noch verstärkt wurde und somit die positive Wirkung einer besseren Wasserversorgung abmilderte bzw. überdeckte.

Allgemein war die günstige Wirkung der **Polymergabe** in Verbindung mit den verschiedenen **Boden-Bewässerungskombinationen** bezüglich der Rispen- und TM-Bildung sehr ähnlich. Auf **mittlerem Boden** war eine fördernde Wirkung der Polymergabe bei geringer und mittlerer Bewässerungsfrequenz (M 12 und M 8) deutlich erkennbar, was einer Minderung des Wassermangels zugeschrieben werden kann. Die Wirkungslosigkeit der Polymergabe bei hoher Bewässerungshäufigkeit ist mit einer an sich günstigen Wasserversorgung dieser Boden-Bewässerungskombination zu erklären. Diese Ergebnisse belegen, dass es möglich ist, die Bewässerungsfrequenz durch Polymergabe von 4- auf 8-tägig ohne Nachteil zu reduzieren. Zu ähnlicher Schlussfolgerung gelangten HÜTTERMANN *et al.* (1997) in Versuchen an *Populus*, in denen die Bewässerung in einem längeren Intervall reduziert wurde und ein vermindertes Wachstum je nach Höhe der Polymerzugabe erst deutlich verzögert eintrat. Auch Experimente von DEHGAN *et al.* (1994); DEHGAN (1995) sowie STILL (1976) weisen in die gleiche Richtung. Auf **schwerem Boden** hatte die Bewässerungsfrequenz kaum einen Effekt auf die Rispenanzahl und TM, dennoch wirkten Polymergaben bei S 12, S 8 und S 4 in ähnlichem Umfang (tendenziell bzw. signifikant, Abb. 2 und 3). Dies könnte auf einer Minderung von Verschlämmung und Stauwasser infolge eines durch Polymere verbesserten, stabileren Bodengefüges beruhen.

Auf dem **leichten Boden**, einem humusarmen Sand, war die Wasserspeicherung allgemein so gering, so dass ohne polymere Bodenverbesserer nur bei hoher Bewässerungsfrequenz eine sehr geringe Rispen- und TM-Bildung möglich war, welche mit Polymergabe schon bei mittlerer Frequenz erreicht wurde und bei hoher Frequenz noch deutlich übertroffen wurde. Auf sehr leichtem Boden ist allerdings eine angemessene Hirseproduktivität nur bei hoher Bewässerungsfrequenz und Polymereinsatz zu erzielen. In die gleiche Richtung weisen Untersuchungen von GEESING und SCHMIDHALTER (2004), in denen eine signifikante Erhöhung der Trockenmasse bei Weizen nur erzielt wurde, wenn durch die Polymere ein Wassermangel vermieden wurde.

Insgesamt zeigen die Untersuchungen, dass Polymereinsatz auf mittleren und leichten Böden die Wasserversorgung und die Produktivität von annuellen Pflanzen wie Futterhirse verbessern kann, und bei mittlerem Boden die notwendige Bewässerungsfrequenz und damit auch Arbeit sowie Kosten gesenkt werden können. Dies bestätigen Untersuchungen von SIVAPALAN (2001a), anhand steigender Erträge von Sojabohnen aufgrund zunehmender Polymergaben bzw. gleicher Erträge, wenn bei höherer Polymerzugabe die Bewässerungsfrequenz erniedrigt wurde.

In einer weiteren Arbeit belegte SIVAPALAN (2001b) auf leichtem Boden eine verbesserte Wasserspeicherung durch Polymerzusatz, welche in unserem Versuch auf allen drei Böden auch die N-Auswaschung verringerte. Dabei ist die unerwartete höhere N -Auswaschung bei 8-tägiger im Vergleich zur 4-tägigen Bewässerung vermutlich auf die geringere Biomassebildung (Tab. 4) bzw. damit auch verringerter N-Aufnahme durch die Pflanzen nach der zweiten N-Gabe zur Blüte zurückzuführen. Die Versuche von SYVERTSEN und DUNLOP (2004) weisen auch darauf hin, dass durch Polymerzusatz zu einem Sandboden die N-Aufnahme von Citrusssämlingen zunahm und darüber hinaus auch eine N-Auswaschung dort verhindert wurde.

Es bleibt zu prüfen, ob die allgemeine Förderung der Pflanzen durch Polymerzugabe auf schweren Böden (s u L) eventuell auf einer Strukturverbesserung des Bodens im Sinne einer besseren Belüftung beruhte.

Effects of a Polymer for Soil Amendation on Yield Formation of Millet under Arid Conditions

Summary

In arid and semiarid regions water is one of the main limiting factor for plant production. With regard to advantages of an improved water-holding capacity in such regions, we investigated the effects of polymer addition (0,3 % w/w) to three soils (light, medium and heavy) and of three irrigation frequencies (every 4, 8 or 12 days) on the survival and growth of *Panicum antidotale* Retz and on nitrogen leaching under the climatic conditions of north-west Iran.

40 d after sowing survival rate of millet decreased progressively, particularly on the light soil and at a low irrigation frequency. Polymer admixtures and high irrigation frequencies provoked marked positive effects on all plant traits with significant interactions with soils. On all soils, but particularly on the medium soil which favored panicle and biomass production, the effects of polymers were most pronounced at low and medium irrigation frequencies. The interactions are discussed on the background of an improved water-holding capacity, a better soil aeration, and a reduced leaching of nitrogen due to the polymer admixture.

Keywords: polymer admixture, water-holding capacity, irrigation frequency, millet, Panicum antidotale, nitrogen leaching, survival rate

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Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 107, No. 1, 2006, pages 67–83

Variation in the Response of Seed and Embryonic Axes to Incubation Temperature Gradients during Seed Treatments in Pearl Millet and Sorghum

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Abstract

Incubation temperature during the presowing soaking of seeds plays a significant role in determining the rate and characteristics of post-treatment germination. Three experiments were conducted on sorghum (*Sorghum bicolor* L Moench) and pearl millet (*Pennisetum glaucum* L. R. Br.) genotypes to determine the influence of constant, alternating, ascending and descending temperature regimes on germination characteristics of seeds after treatment. Incubation temperatures ranging from 10 to 35°C were applied as well as alternating the magnitude and range of day/night temperatures. A third experiment tested a 3-day temperature gradient and its impact on germination and seedling characteristics. All three incubation temperature regimes were combined with various hormonal and mineral seed soaking treatments to test for possible interactive effects. Temperature did not affect the final germination percentage of seeds but influenced the germination rate. Constant temperatures of 20 or 25°C induced higher germinative capacity than alternating or constant temperatures of higher or lower magnitude. Increasing the variance in day/night temperature reduced the rate of germination. Incubating seeds during soaking treatments at a constant 20°C for 3 days yielded better germination characteristics than a thermal gradient of 25/20/15°C. An 8g l^{-1} $NaCl$ treatment induced greater plumule (shoot) growth than non-treated counterparts and treating seeds with GA_3 or salts improved germination characteristics and synchrony of treated seed lots.

Keywords: seed treatments, treatment temperature, germination, plumule, radicle

1 Introduction

Emergence and establishment of rainfed sorghum and pearl millet may not always be completely successful since, after imbibition, any water shortage delays emergence, exposing the seeds to stress (Al-Mudaris, 1998b; Kader, 2001; Kader and Jutzi, 2001). Therefore, there has recently been an upsurge of interest in the use of presowing seed treatments involving full or partial hydration of seeds, which may improve emergence and subsequent establishment (Gurushinghe *et al.*, 1999; Powell *et al.*, 2000; Gallardo *et al.*, 2001; Harris, 2001; Araus *et al.*, 2002; Kader and Jutzi, 2002).

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Such treatments include the soaking of seeds in high osmotic potential solutions for various periods of time (Heydecker, 1978; Heydecker and Gibbins, 1978; Brocklehurst and Dearman, 1984; Demir and van de Venter, 1999; Gosling *et al.*, 1999; Lin and Sung, 2001). Temperature, which is an important variable in such treatments, has both qualitative and quantitative effects on subsequent germination rates of treated seeds (Heydecker *et al.*, 1973; Argerich and Bradford, 1989; Hardegree, 1994; Hampton *et al.*, 2000). Reports on the optimum incubation temperature have been inconsistent and do not lend themselves to easy interpretation. Booth (1992) imbibed seeds of *Eurotica lanata* at temperatures from 0 to 20°C in 5°C increments and found that as imbibition temperature increased from 5 to 15°C the probability of successful germination after soaking decreased. Brocklehurst and Dearman (1984) primed carrot, celery, leek and onion seeds at 15°C, whereas Rennick and Tiernan (1978) used 18°C. Other treatment temperatures have been reported ranging from 20°C for carrot (Austin *et al.*, 1969) to 25°C for pepper seed (Georghiou *et al.*, 1987) spanning a wide array of temperature gradients (Welbaum *et al.*, 1998; Pritchard *et al.*, 1999; Kolasinska *et al.*, 2000; Steinmaus *et al.*, 2000; Iannucci *et al.*, 00; Wuebker *et al.*, 2001). The priming of sorghum and pearl millet has not been well documented in the literature, and investigation of the effects of both constant and alternate priming temperature gradients is important in stress acclimation treatments (Al-Mudaris, 1998b; Glenn and Brown, 1998). The objective of the experiments reported here was to study the influence of incubation temperature during priming with various agents on subsequent germination rate of sorghum (*Sorghum bicolor* L. Moench) and pearl millet (*Pennisetum glaucum* L. R. Br.) seeds. Both constant and alternate temperature regimes were tested in addition to a sequential regime involving gradual temperature increases or decreases throughout the treatment period, thus creating a temperature gradient.

2 Materials and Methods

2.1 Constant incubation temperatures

Four seed treatments including a dry control were applied to four sorghum and pearl millet genotypes. All four accessions were obtained from the Asia Centre of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Patancheru, India. These included sorghum varieties ICSV 745 and M35-1, the pearl millet variety CZ-IC 923 and the pearl millet hybrid HHB 67. All seeds were tested following International Seed Testing Association regulations (ISTA, 1993) and revealed germination percentages of 95.7 to 99.3%, moisture content of 13.3 to 14.9% and viability (tetrazolium) of 99.7 to 100%. One thousand (1000) seed weights were 30.3, 38.9, 13.3 and 13.5g for ICSV 745, M35-1, CZ-IC 923 and HHB 67, respectively.

Seed treatments included soaking seed in 150 mg l^{-1} gibberellic acid (GA_3) (150 ppm), 150 mg l^{-1} kinetin (150 ppm), 5g KNO_3 l^{-1} (5%) or 5g l^{-1} $NaCl$ (5%) for 3 days (d). The control included dry, untreated seeds. All 4 seed treatments and the dry control were incubated during the 3-day (d) period at one of six temperatures. These were 10, 15, 20, 25, 30 or 35°C in incubation chambers in the dark (Conviron Industries, Canada). After treatment, seeds were retrieved from solutions, washed in distilled water and sown in 1-litre polystyrene trays. Two hundred (200) seeds were sown per tray between creased filter paper and each treatment combination replicated 6 times. Trays were placed in a germination cabinet set at a constant 35°C temperature in the dark to allow germination. Germination counts were taken at 24 hour (h) intervals for 10 d and from them the final germination percentage (FGP), first day of germination (FDG), mean germination time (MGT) and germination rate index (GRI) calculated. MGT and GRI were calculated following ORCHARD (1977) and BENECH ARNOLD *et al.* (1991), respectively. Data were arcsine transformed (YANG *et al.*, 1999; HOULE *et al.*, 2001) and subjected to an analysis of variance with mean separation at the 5 % level of probability using the General Linear Model of the SAS® statistical package (SAS Institute, USA) (SAS, 1989; BARRILLEAUX and GRACE, 2000). Trays were arranged in a Randomised Complete Block Design (RCBD) inside incubators and data exposed to one-way and two-way ANOVA (WEBER and ANTONIO, 1999).

2.2 Alternating incubation temperatures

A dry, untreated and a wet, water-soaked (distilled water) control were included in this experiment in addition to two sodium chloride-based ($NaCl$) treatments. These were 4 and 8g $l^{-1}NaCl$ solutions having an osmometer-measured (Wescor, Utah, USA) osmotic potential (Ψ_s) of -3.2 and -5.7 bar, respectively (circa -0.3 and -0.5 MPa, respectively).

Seeds of sorghum SPV 462, an ICRISAT variety, were either untreated (dry control), soaked in distilled water (wet control) or soaked in the $NaCl$ solutions for 3 d. Incubation temperatures during treatment included a constant 25°C regime and 3 alternate regimes. These were 25/20°C (12 h/12 h day/night), 25/15°C and 25/10°C. Treatments were conducted in the dark. After treatment, seeds were washed in distilled water and dried back at 25°C for 48 h to their original weight in a constant air flow cabinet (Heraeus Voetsch, Germany). Batches of 200 seeds were then sown in 1-liter polystyrene trays between creased filter paper. The paper was moistened with 50 ml of a polyethylene glycol solution (PEG molecular weight 10,000 Sigma Chemical, St Louis, USA) producing a drought level of -10 bar (-1 MPa). As an osmotic agent, PEG is metabolically inert and is ideal for simulating drought (SALISBURY and ROSS, 1992; SWAGEL *et al.*, 1997).

Trays were covered with transparent lids, replicated 6 times and placed in an incubator at 42/18°C (12 h/12 h day/night). Germination was scored daily for a period of 10 d and from the data the FGP, MGT and germination index (GI) were calculated (AL-MUDARIS, 1998a). GI assigns maximum weight to seeds germinating on the first day and less weight to seeds germinating thereafter (BENECH ARNOLD *et al.*, 1991). At the end of the test, 20 seedlings were randomly taken from the 20 middle creases in the filter paper and their plumules and radicles excised and weighed after drying at 80°C for 4 d in a reverse cycle oven (Conviron Industries, Canada). These produced the dry weight of plumule (DWP), dry weight of radicle (DWR) and the plumule to radicle ratio (PRR), which is the product of DWP divided by DWR. Statistical procedures were similar to the constant incubation temperature experiment.

2.3 Ascending and descending temperatures

The same batch of SPV 462 seeds was used in this test. Seeds were either untreated (dry control), soaked in 4g NaCl l-1 (4%) or soaked in 4g l^{-1} KCl (4%) for 3 d. Three temperature regimes were applied during soaking treatments as follows:

Regime 1 (R1): Seeds in soaking solutions exposed to 25°C on the first day of treatment, 20°C on the second day and 15°C on the third day.

Regime 2 (R2): Seeds in soaking solutions exposed to 15°C on the first day of treatment, 20°C on the second day and 25°C on the third day.

Regime 3 (R3): Seeds exposed to a continuos 20°C during the whole 3 d treatment period.

Seeds were retrieved from the solutions, dried as in the previous experiment and sown in batches of 200 in polystyrene trays in 6 replicates. Fifty (50) ml of the -10 bar PEG solution was applied to each tray and, thereafter, trays incubated at 39/15°C (12 h/12 h day/night) in the dark. Germination scores were taken daily for the first 10 d and the FGP, MGT and GI calculated. On the 11th day, 20 seedlings were randomly taken as in the previous experiment and their DWP, DWR and PRR recorded.

3 Results and Discussion

3.1 Constant incubation temperatures

Single factor analysis showed that soaking treatments did not have a significant effect on the FGP or GRI of sorghum or pearl millet seed (Table 1). Germination speed as reflected by the FDG and MGT was, however, significantly increased by seed treatments in comparison to controls. GA_3 generally gave the fastest germination (Table 1).

Genotypes differed significantly in their germination characteristics (Table 1). The sorghum variety ICSV 745 gave the highest overall FGP and GRI pooled over treatments and incubation temperatures followed by the pearl millet variety CZ-IC 923, the hybrid HHB 67 and the sorghum variety M35-1. The slowest initiation and rate of germination were observed in HHB 67 as illustrated in Table 1. Incubation temperature also had a significant effect on the FGP, FDG, MGT and GRI. The 35°C incubation temperature resulted in the lowest FGP followed by 30°C, whereas the 10°C regime caused germination to initiate later and take longer time to complete. The 25°C regime was optimal in terms of this initiation and ending of germination as seen from FDG and MGT values (Table 1).

Interactive analysis of genotype×temperature effects (Table 2) revealed the same trend. Thirty and 35°C reduced the FGP and germination speed was generally increased by an increase in incubation temperature. Seed treatment × genotype analysis showed no general preference of a genotype to one specific treatment (data not shown). The same applied to seed treatment×incubation temperature effects, where no single treatment generally preferred a particular temperature but rather an overall effect of temperature in reducing the FGP as it rose to 35°C was detected (data not shown).

Table 1: Effect of seed treatments, genotype and incubation temperature on germination characteristics of sorghum and pearl millet.

	FGP (%)	*FDG (day)*	*MGT (day)*	*GRI (%/day)*
Seed Treatment				
Dry Control	65.8 ^{a}	3.6 ^{a}	3.8 ^{a}	15.4 ^{a}
GA_3	67.6 ^{a}	3.3 ^{b}	3.4 ^{b}	16.3 ^{a}
Kinetin				
64.2 ^{a}	3.5 ^{ab}	3.6 ^{b}	15.1 ^{a}	
KNO_3	64.1 ^{a}	3.5 ^{a}	3:6 ^{ab}	15.4 ^{a}
NaCl	63.6 ^{a}	3.5 ^{a}	3.6 ^{ab}	14.4 ^{a}
Genotype				
ICSV 745	87.0 ^{a}	3.3 ^{b}	3.4 ^{b}	22.1 ^{a}
M35-1	45.2 ^{d}	3.4 ^{b}	3.5 ^{b}	10.3 ^{d}
CZ-IC 923	66.1 ^{b}	3.5 ^{b}	3.6 ^{b}	15.6 ^{b}
HHB 67	62.0 ^{c}	3.7 ^{a}	3.8 ^{a}	13.3 ^{c}
Incubation Temp. ($^{\circ}$C)				
10	71.3 ^{a}	3.9 ^{a}	4.0 ^{a}	14.8 ^{ab}
15	71.8 ^{a}	3.6 ^{b}	3.7 ^{b}	15.5 ^{ab}
20	70.3 ^{a}	3.4 ^{b}	3.5 ^{b}	16.0 ^{a}
25	68.2 ^{a}	3.1 ^{c}	3.2 ^{c}	17.2 ^{a}
30	58.5 ^{b}	3.4 ^{b}	3.5 ^{c}	15.2 ^{ab}
35	50.3 ^{c}	3.5 ^{b}	3.6 ^{b}	13.2 ^{b}

Means of treatment effects within columns followed by a similar letter are not significantly different at 5%. The same applies to means of genotype and incubation temperature effects. FGP: Final Germination Percentage, FDG: First Day of Germination, MGT: Mean Germination Time and GRI: Germination Rate Index.

3.2 Alternating incubation temperatures

The FGP of dry controls was significantly higher than that of either the wet control or the two NaCl treatments. However, the MGT of the dry control was also higher meaning that it germinated slower than those seeds that were soaked (Table 3). Due to the higher FGP of the dry control it attained a higher GI value at the end of the test. The dry weight of plumules of seeds treated with the 8g l^{-1} NaCl solution was significantly greater than those of all other treatments (Table 3), which did not differ from each other in this respect. The DWR and PRR did not differ amongst treatments.

Table 2: Interactive effects of genotype and incubation temperature on germination characteristics of sorghum and pearl millet.

Genotype	*Incubation Temp. (°C)*	*FGP (%)*	*FDG (day)*	*MGT (day)*	*GRI (%/day)*
ICSV 745	10	87.5 ^{ab}	4.1 ^{ab}	4.1 ^{ab}	18.7 $^{b-d}$
	15	92.5 ^{a}	3.8 $^{b-d}$	3.8 $^{b-d}$	20.9 $^{a-c}$
	20	86.0 ^{b}	3.4 $^{d-f}$	3.6 $^{d-f}$	20.9 $^{a-c}$
	25	88.0 ^{ab}	3.2 $^{e-g}$	3.3 $^{e-g}$	23.3 ^{ab}
	30	85.0 ^{b}	2.9 ^{gh}	2.9 ^{g}	24.0 ^{a}
	35	83.0 ^{bc}	2.7 ^{h}	2.8 ^{g}	24.9 ^{a}
M35-1	10	42.0 ^{gh}	4.0 $^{a-c}$	4.1 $^{a-c}$	8.1 ^{i}
	15	47.5 ^{gh}	3.6 ^{de}	3.6 ^{de}	9.2 ^{hi}
	20	51.5 ^{g}	3.5 $^{d-f}$	3.6 $^{d-f}$	11.8 $^{e-i}$
	25	48.5 $^{f-h}$	3.2 $^{e-g}$	3.2 $^{e-g}$	10.4 $^{g-i}$
	30	45.0 ^{gh}	3.5 $^{d-f}$	3.6 $^{d-f}$	11.7 $^{e-i}$
	35	37.0 ^{h}	2.9 ^{gh}	2.9 ^{g}	10.6 $^{g-i}$
CZ-IC 923	10	81.5 ^{bc}	3.8 $^{b-d}$	3.8 $^{b-d}$	17.1 ^{cd}
	15	81.5 ^{bc}	3.5 $^{d-f}$	3.5 $^{d-f}$	18.4 $^{b-d}$
	20	68.5 ^{de}	3.4 $^{e-f}$	3.5 $^{d-f}$	15.7 $^{d-f}$
	25	67.0 ^{de}	3.1 $^{e-g}$	3.2 ^{fg}	17.0 ^{cd}
	30	60.5 ^{ef}	3.2 $^{e-g}$	3.2 $^{e-g}$	16.0 $^{c-e}$
	35	38.0 ^{h}	4.1 ^{ab}	4.2 ^{ab}	9.4 ^{hi}
HHB 67	10	74.3 ^{cd}	3.8 $^{a-d}$	3.9 $^{b-d}$	15.1 $^{e-g}$
	15	66.0 ^{de}	3.7 ^{cd}	3.7 $^{c-e}$	13.7 $^{e-h}$
	20	75.5 ^{cd}	3.4 $^{d-f}$	3.5 $^{e-f}$	15.5 $^{d-f}$
	25	69.5 ^{de}	3.1 $^{e-h}$	3.1 ^{fg}	18.1 ^{cd}
	30	43.5 ^{gh}	4.3 ^{a}	4.4 ^{a}	9.1 ^{hi}
	35	43.5 ^{gh}	4.2 ^{a}	4.4 ^{a}	8.0 ^{i}

Means in columns followed by similar letters are not significantly different at 5%.

FGP: Final Germination Percentage, FDG: First Day of Germination, MGT: Mean Germination Time and GRI: Germination Rate Index.

Table 3: Effect of seed treatments and incubation temperatures on germination and seedling characteristics of sorghum SPV 462 seeds.

	FGP (%)	*MGT (day)*	*GI*	*DWP (mg)*	*DWR (mg)*	*PRR*
Seed Treatment						
Dry Ctrl.	82.8 ^{a}	4.0 ^{a}	535.4 ^{a}	1.0 ^{b}	1.5 ^{a}	0.83 ^{a}
Wet Ctrl.	61.2 ^{b}	3.5 ^{b}	432.2 ^{bc}	1.3 ^{b}	1.7 ^{a}	0.88 ^{a}
4g/l $NaCl$	58.0 ^{b}	3.3 ^{bc}	401.7 ^{c}	1.1 ^{b}	1.6 ^{a}	0.75 ^{a}
8g/l $NaCl$	53.0 ^{b}	2.9 ^{c}	486.6 ^{ab}	2.0 ^{a}	2.1 ^{a}	0.97 ^{a}
Incubation Temp. (°C)						
25	68.5 ^{a}	3.1 ^{b}	521.4 ^{a}	1.4 ^{a}	2.3 ^{a}	0.64 ^{a}
25/20	64.9 ^{a}	3.3 ^{b}	476.1 ^{ab}	1.2 ^{a}	1.5 ^{b}	0.89 ^{a}
25/15	63.0 ^{a}	3.9 ^{a}	426.0 ^{b}	1.3 ^{a}	1.5 ^{b}	0.93 ^{a}
25/10	58.5 ^{a}	3.5 ^{ab}	432.5 ^{b}	1.5 ^{a}	1.6 ^{ab}	0.97 ^{a}

Means of treatment effects within columns followed by a similar letter are not significantly different at 5%. The same applies to means of incubation temperature effects.
FGP: Final Germination Percentage , MGT: Mean Germination Time, GI: Germination Index, DWP: Dry Weight of Plumule, DWR: Dry Weight of Radicle, PRR: Plumule/Radicle Ratio, Dry Control: untreated seeds, and Wet Control: Water-soaked seeds.

Incubation temperature also did not seem to have an effect on the FGP of sorghum seeds (Table 3), but affected germination speed as seen from the MGT values. The 25°C constant temperature regime gave faster germination than the 25/15°C regime. The GI was also higher for the 25°C regime than the 25/15 or 25/10°C regimes (Table 3). Neither DWP nor PRR were affected by incubation temperature even though the DWR was higher at 25°C than at 25/20 or 25/15°C.

Interactive analysis between seed treatments and temperature regimes revealed no preference of treatments for a certain temperature but a tendency of water-soaked seeds to perform better under the 25°C regime than under others (data not shown). Otherwise, the same results as those of single factor effects were observed.

3.3 Ascending and descending temperatures

As seen from Table 4, the 4g l^{-1} KCl treatment, pooled over all three temperature regimes, yielded a significantly lower FGP than the dry control and the 4g l^{-1} $NaCl$ treatment. Again, the effect of soaking treatments was that of increasing germination speed as seen by lower MGT values in the salt soaks.

The 4g l^{-1} $NaCl$ treatment gave the best FGP×MGT relationship as it yielded the highest GI value. Seedling characteristics, represented by DWP, DWR and PRR were

Table 4: Effect of seed treatments and incubation temperature sequences on germination and seedling characteristics of sorghum SPV 462.

	FGP (%)	*MGT (day)*	*GI*	*DWP (mg)*	*DWR (mg)*	*PRR*
Seed Treatment [1]						
Dry Ctrl.	84.0 ^{a}	3.9 ^{a}	593.3 ^{b}	2.4 ^{a}	2.1 ^{a}	1.1 ^{a}
4g/l $NaCl$	84.7 ^{a}	2.9 ^{b}	678.8 ^{a}	2.6 ^{a}	2.6 ^{a}	1.0 ^{a}
4g/l KCl	78.2 ^{b}	3.3 ^{b}	593.7 ^{b}	2.8 ^{a}	2.6 ^{a}	1.0 ^{a}
Incubation Temp. (°C) [2]						
25/20/15	81.6 ^{a}	3.8 ^{a}	584.4 ^{a}	2.8 ^{a}	2.9 ^{a}	0.9 ^{b}
15/20/25	82.8 ^{a}	3.3 ^{ab}	631.4 ^{a}	2.7 ^{ab}	2.2 ^{b}	1.2 ^{a}
20	82.4 ^{a}	3.0 ^{b}	651.1 ^{a}	2.3 ^{b}	2.1 ^{b}	1.0 ^{ab}

[1] : Means of treatment effects within columns followed by similar letters are not significantly different at 5%. The same applies to means of temperature effects.

[2] : Alternating temperatures indicate temperatures on days 1, 2 and 3, respectively and 20°C represents a continuos temperature for the whole 3 d period.

FGP: Final Germination Percentage , MGT: Mean Germination Time, GI: Germination Index, DWP: Dry Weight of Plumule, DWR: Dry Weight of Radicle and PRR: Plumule/Radicle Ratio.

not affected by soaking treatments. The sequence of incubation temperature did not play a role in the FGP of seeds, but rather in the MGT (Table 4). Seeds incubated under the 20°C constant temperature regime germinated faster than those incubated under the 25/20/15°C sequence (R1). There was no significant difference between R1, R2 and R3 in GI terms. The growth of plumules and radicles in addition to their ratio was affected by temperature regime, as 25/20/15°C gave significantly higher DWP than both 15/20/25°C and 20°C. The difference in weight between plumules and radicles in favour of the former was more pronounced at 4g l^{-1} $NaCl$ in R2 than in R1, thus yielding higher PRR values in the former (Table 5).

The general picture which emerges from the data is that the seed soaking treatments reported seem to be more efficient in increasing germination speed than its final percentage. This effect appears not to be altered by post treatment drying of the seed since the general line of effects observed in the first experiment where seeds were sown fresh was also observed in the dried-back seeds of the second and third experiments. Moreover, the three experiments included different temperature and moisture conditions. The constant temperature experiment was conducted at 35°C without inducing drought, whereas the alternating temperature experiment had a 42/18°C day/night temperature averaging 30°C on a 24 h basis. It also received a PEG-induced drought treatment of -10 bar as did the third experiment. This would tend to point to flexibility in the

Table 5: Interactive effects of seed treatments and incubation temperature sequences on germination and seedling characteristics of sorghum SPV 462 seeds.

Seed Treatment	*Incubation Temp. (°C)*[1]	*FGP (%)*	*MGT (day)*	*GI*	*DWP (mg)*	*DWR (mg)*	*PPR*
Dry Ctrl.	25/20/15	85.3 ^{b}	4.0 ^{a}	588.3 ^{d}	2.8 ^{a}	2.6 ^{bc}	1.0 $^{a-c}$
	15/20/25	84.6 ^{b}	3.9 ^{a}	598.6 ^{cd}	2.5 ^{ab}	2.0 ^{cd}	1.2 ^{ab}
	20	82.0 ^{bc}	3.7 ^{ab}	593.0 ^{d}	2.0 ^{b}	1.8 ^{d}	1.0 $^{a-c}$
4g NaCl/l	25/20/15	82.3 ^{bc}	3.6 ^{ab}	603.0 ^{cd}	2.8 ^{a}	3.3 ^{a}	0.8 ^{c}
	15/20/25	91.0 ^{a}	2.8 ^{cd}	742.3 ^{a}	3.1 ^{a}	2.3 $^{b-d}$	1.3 ^{a}
	20	81.0 ^{bc}	2.4 ^{d}	691.3 ^{ab}	2.1 ^{b}	2.1 ^{cd}	0.9 ^{bc}
4g KCl/l	25/20/15	77.3 ^{cd}	3.7 ^{ab}	559.0 ^{d}	2.8 ^{a}	2.9 ^{ab}	1.0 $^{a-c}$
	15/20/25	73.0 ^{d}	3.3 a-c	553.3 ^{d}	2.5 ^{ab}	2.5 $^{b-d}$	1.0 $^{a-c}$
	20	84.3 ^{b}	3.0 $^{b-d}$	669.0 ^{bc}	3.0 ^{a}	2.5 ^{bc}	1.1 $^{a-c}$

Means within columns followed by similar letters are not significantly different at 5%.
[1] : Alternating temperatures indicate temperatures on days 1, 2 and 3, respectively and 20°C represents a continuos temperature for the whole 3 d period.
FGP: Final Germination Percentage , MGT: Mean Germination Time, GI: Germination Index, DWP: Dry Weight of Plumule, DWR: Dry Weight of Radicle and PRR: Plumule/Radicle Ratio.

response of sorghum and pearl millet seeds to soaking treatments within the range between 27 and 35°C during germination, confirming earlier reports (Ziska and Bunce, 1993; Forcella *et al.*, 2000; Tiryaki and Andrews, 2001; Harris, 2001).

Incubation temperature during treatment, on the other hand, seems to act in another way. A constant temperature during seed soaking appears to be more favourable for post-treatment germination than an alternating regime. In the first experiment, seeds were exposed to constant temperatures ranging from 10 to 35°C. In the second experiment the 25/20, 25/15 °C and 25/10°C regimes gave a 24 h average of 22.5, 20.0 and 17.5°C, respectively. Nevertheless, the average temperature during a day in soaking seems not to be the critical point. More significant appears to be the change in temperature, be it increasing or decreasing, during treatment. This could be confirmed by the data of the third experiment. The 25/20/15 and 20°C regimes all averaged 20°C over the 3 d soaking period. This 20°C given in one constant bulk of heat units (R3), however, yielded better post-treatment results than an increasing (R1) or decreasing (R2) regime. The upper limit of temperature with which one may treat seeds of the genotypes tested is 30°C. Temperatures over 30°C (i.e 35°C in this investigation) yielded poor results. Also, some seeds were observed to germinate during treatment as early as 24 h after initial soaking at 30 and 35°C. This was most severe in pearl millet HHB 67 and less in the M35-1 sorghum variety, and confirms earlier tests (Al-Mudaris and Jutzi, 1998b,c,a, 1999a,b).

Generally, but not always significantly, a rise in incubation temperature during treatment increased post-treatment germination speed, which agrees with the data of Khan *et al.* (1980) who obtained higher germination rates at 20°C in comparison to 10 or 15°C. However, no effect on the FGP was detected. The fact that 12 h a day of temperatures 20°C or lower (i.e. 20, 15 and 10°C in the second experiment) during a 24 h cycle, or for 24 h during a 72 h cycle (R1 and R2 treatments of the third experiment) were not as effective as the constant 20°C may point to an absolute temperature preference by soaked seeds. This means that if a threshold "low" is reached, certain changes may occur within the seed that are dependent on future temperatures in a way that may be similar to certain qualitative light responses in flowering plants. Lima bean (*Phaseolus lunatus* L.) seeds imbibed at 15°C and then allowed to germinate and grow at 25°C have been shown to produce smaller seedlings (Pollock and Toole, 1966). Thus, sensitivity to chilling injury during the first 10 minutes of imbibition has been proposed (Pollock and Toole, 1966; Kester *et al.*, 1997; Al-Mudaris, 1998b; Kolasinska *et al.*, 2000; Massardo *et al.*, 2000; Gallardo *et al.*, 2001; Kader and Jutzi, 2002). Hegarty (1978) concluded that increased injury during soaking in some species at 10 or 30°C compared to 20°C is associated with greater losses of solutes from the seeds. Simon and Wiebe (1975), on the other hand, reported that the extent of leakage depends on initial water content of the seeds, being very low if embryos already have a water content of 30% or more (Ψ_s of -80 bars) before soaking. This would not apply to the seed batches used in these experiments since moisture contents of seeds were within the normal limits of circa 13-15.0 %.

Seeds in experiments 2 and 3 were dried back after treatment and it has been reported that embryos imbibed for 60 minutes, dried and returned to water again show a rapid leakage of solutes (Bewley and Black, 1978a,b). This may be one of the reasons why dry controls gave higher FGP values in experiment 2. Imbibition at a high temperature of 35°C also increases sensitivity to ethylene (Zarnstorff *et al.*, 1994) whilst at 30°C cytokinin passage from the cotyledon to the embryonic axis is affected (Eloisa Revilla *et al.*, 1988). Hassan *et al.* (1985) observed decreased auxin concentrations with time in seeds of *Anemone coronaria* and *Ranunculus asiaticus* at 8°C compared with 24°C during soaking. Chen *et al.* (1983) reported reduced germination of chickpea seeds down to 30% when soaked at 2°C compared to 95% at 20°C. This tends to point to the presence of a threshold minimum and/or maximum below or above which seeds respond through a number of physiological events.

An increase in soaking temperature affected germination speed. This is in agreement with the results of Argerich and Bradford (1989) and Hardegree (1994), who showed increases in germination rate with rises in temperature up to 25°C. Heydecker *et al.* (1973) arrived at similar conclusions, and Khan *et al.* (1978) found that osmoconditioning celery seeds at 15°C was not as effective as at 20°C in shortening the germination period. Cotton seed germination has been found to be affected by presowing imbibition temperature. McCarty (1992), studying cyclic temperature schemes, indicated that imbibing seeds at 10°C resulted in more adverse effects than imbibing at 25°C. Keeping seeds at 10°C for periods greater than 24 h reduced seedling emergence compared with keeping seeds at 10°C for 24 h then increasing substrate temperature. Increasing substrate temperature after 48 h of exposure to 10°C was found not to reverse the damaging effects of low temperatures. This tends to confirm the conclusion that 20 to 25°C is the optimal treatment temperature.

The effect of soaking treatments on the germination and early axis growth of seedlings may not be attributed to the Ψ_s of solutions, which would decrease water uptake as it drops (Gurmu and Naylor, 1991), but rather to possible physiological or ionic effects (Al-Mudaris, 1998b; Dewar *et al.*, 1998; Ren and Kermode, 1999; Richards *et al.*, 2001; Tiryaki and Andrews, 2001). In experiment 1 the 5g l^{-1} KNO_3 solution measured -2.4 bar on the osmometer vs. -3.9 bar for 5g l^{-1} NaCl. The Ψ_s of 4g l^{-1} NaCl and 8g l^{-1} NaCl solutions in the second experiment were -3.2 and -5.7 bar, respectively and that of 4g l^{-1} KCl in experiment 3 was -2.4 bar. It follows that differences were not large in the Ψ_s between treatments and it is, thus, difficult to trace back results to this factor, which would typically arise from notable differences in Ψ_s (Hadas and Russo, 1974).

The greatest increase in germination speed in the constant temperature experiment was in the GA_3 treatment. The production of gibberellin is speculated to be a prerequisite for radicle emergence (Bewley and Black, 1978a; Wang *et al.*, 1998; Lin *et al.*, 1998; Pedersen and Toy, 2001; Ljung *et al.*, 2001). Additionally, cell extension of plant tissue is generally held to be regulated by hormones, especially auxins and gibberellins and, since germination culminates in radicle emergence, which in most cases comprises only cell enlargement and not necessarily cell division (Bewley and Black, 1978a; Dominguez and Cejudo, 1999; Nascimento and West, 2000; Lahuta *et al.*, 2000), the promotive role of GA_3 in increasing germination speed is not surprising. Additionally, on the premise that germination may involve the synthesis of specific proteins/enzymes, the possibility that GA_3 may have an effect on protein and/or RNA synthesis (Bewley and Black, 1978b) still remains open. Exogenous application of GA_3 has been reported to stimulate growth (Kozlowski, 1972) and germination percentages and rates in sorghum seeds soaked for 4-6 days in 500 or 750 ppm GA_3 at 15 and 20°C (Santipracha, 1986).

KCl was not as effective as NaCl since it yielded lower FGPs in the third experiment. The observed difference may lie within the K^+ and Na^+ ions since Cl^- is common between the two compounds. Potassium is characterized by high mobility in plants at cellular, tissue or long distance transport levels (Marschner, 1995) and seems essential for the synthesis of metabolites (Kozlowski, 1972). Sodium is less essential than K^+ as a mineral nutrient (Marschner, 1995). The 4g l^{-1} KCl and 4g l^{-1} NaCl solutions had almost the same pH values of 5.84 and 5.87, respectively, and electrical conductivity values of 7.35 and 6.92 mS cm^{-1}, respectively. Thus, other internal effects may have played a role since a relationship between potassium, magnesium and phosphate ions, and gibberellic acid is known to exist (Bewley and Black, 1978a). Influx of Na^+, Cl^- and K^+ ions into the seed may have altered the response to temperature as these have an impact on physiological triggers (Keiffer and Ungar, 1997; Glenn and Brown, 1998; Howard and Mendelssohn, 1999; Gaxiola *et al.*, 2001).

In conclusion it is recommended that ambient room temperatures of 20 to 25°C be used for the soaking treatments reported since gains through alternating temperatures were not observed. It would also be interesting to validate the effect of GA_3 on sorghum and millet seeds under other conditions and to further investigate the effects of Na^+ and K^+ in seed priming treatments.

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Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 107, No. 1, 2006, pages 85–94

Estimation of Erosion Danger Lands of the Reclamation Fund in Georgia

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Abstract
Erosion danger of lands of the reclamation fund in Georgia was studied by means of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978), which was modified in the Problem Lab of Soil Erosion and River Bed Processes of Moscow State University (Anonymous, 1982). By the investigation was established that average annual potential soil loss, which was counted by means of USLE, is 10,5 % less than real loss of soil. If for the calculation of the potential soil loss we use only rains which provoke soil erosion, the difference between real and counted soil losses is only 1.77 % i.e. exactness of soil erosion forecast increases 5-6 times.

Keywords: Georgia, erosion danger, lands of Georgia, erosion forecast, USLE

1 Introduction

The climate of of Western Georgia is humid subtropical and that of Eastern Georgia arid subtropical. In the hilly regions of Western Georgia only 0,3-1,5 % of the territory are occupied by arable lands and eroded area is decreased to 30-60 %. Lands of reclamation fund of Georgia include most part of the arable lands.

Georgia is a mountainous country, 70 % of its territory is occupied by mountains. Western and Eastern Georgia is divided by the Ajara-Imereti (Likhi) range which is also watershed of the Black and Caspian Sea basin. There is an elevation of southern Georgia. Eastern Georgia includes volcanic upland (volcanic plateau, with neighboring volcanic ranges) and the hollow of Akhaltsikhi.
As the country is mountainous, it's climate, soils and vegetation changes by the vertical zonality.
By the hydrological investigation it was identified that in Georgia average soil loss is 15-20 tons per hectare. Out of 25 % of total area of the river basin soil losses exceeded 30 t/ha per year (Table 1).

The amount of soil losses from the river basins objectively does not reflect heavy erosion danger on the territory of Georgia. Here, water (rain) erosion and irrigation of erosion on the agricultural lands can be observed, because only 15-20 % of washed out soils are

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Table 1: Annual soil loss by the erosion in the river basins of Georgia

Soil loss (t/ha)	*Area of the river basins (*km^2*)*	
	Western Georgia	*Eastern Georgia*
< 5	–	4,217
5 - 10	5,118	10,803
10 - 15	–	–
15 - 20	5,900	4,980
20 - 30	17,060	4,351
> 30	6,484	10,987

going into a river (Brown, 1984; Kokoreva, 1985). In mountainous regions of the Western Georgia, arable lands occupy only 0,3-1,5 % of the total area. Among them, 80 - 90 % are eroded. In Eastern Georgia area of arable lands increases up to 5-15 % and area of eroded soils decreases from 30 to 60 %.

Considering the above represented facts, it is clear, that studying soil erosion processes and its cartography is inevitable for Georgia. Research and cartography of study results in this field have not yet been conducted in Georgia.

2 Objectives and Methods

Erosion danger of lands was studied by means of the Universal soil Loss Equation (USLE) (Wischmeier and Smith, 1978):

$$A = R * K * S * L * C * P \tag{1}$$

where:
A is the soil loss in t/ha;
R is the rainfall erosivity index (MJ*mm/ha*min*year);
K is the soil erodibility factor (t*ha*min/ha*MJ*mm);
S and L are the dimensionless topographical slope and length factors;
C - the dimensionless cover of soil surface and management factor;
P - the dimensionless specific erosion control practices factor.

The rainfall factor was calculated by the equation of Zaslavski *et al.* (1981):

$$R_{30} = 0,25841 * H * I_{30} - 0.14921 \tag{2}$$

where:
R_{30} is the rainfall factor (MJ mm/ha min year);
H is the amount of rain (mm);
I_{30} is the 30min maximum intensity of rain (mm/min)

By definition, the K factor is the average amount of soil eroded annually from a standard fallow plot (which is of 22.1 m (72.6 f) length on a uniform slope of 9 %, in continuous fallow and tilled up and down the slope) per unit of erosion index (R). This factor was determined using the nomogram and formula of WISCHMEIER and SMITH (1978); WISCHMEIER *et al.* (1971):

$$K = \sum A/R \tag{3}$$

The K or soil erodibility factor is based on six factors: % clay, % silt plus very fine sand, % organic matter, coarse fragment content, permeability and structure (WISCHMEIER and SMITH, 1978).

For estimation of LS-length and steepness factor, on the lands of reclamation fund of Georgia, which contains the most part of arable lands, division into districts was carried out on the map of 1 : 500 000 scale (LITVIN and MIRGORODSKAIA, 1976), the reason of geomorphologic division is separation resembling type of relief. Non-erosion danger area – lowland bog soil area, wide plains soline soils and solonchaks and also sands were seperated onthe map. On the cartographic net for each geomorphological district, the topographical maps were selected 1 : 25 000 scale.

Quantity of maps depends on the area of region dismember of relief. In general, it is desirable for plane regions to take not less than 10 sheets of topographical maps, but foothills, uplands and mountainous region not less than 20 sheets. On the selected sheets of topographical maps, length and inclination of slopes are measured by the point-statistical method (ANONYMOUS, 1982; LITVIN and MIRGORODSKAIA, 1976; LITVIN, 1976). By the above mentioned method of separated points, a big amount of measuring on the map gives an objective characteristic of its average meaning. On each kind of arable land of the geomorphologic district compartment of measurements for various arable lands will be different. If arable land is surplus (70-80 %), then it is quite enough to measure at the knot of the coordinate net. On hay mowing and pasture lands, length and inclination must be measured separately from each other by 1, 1.5, 2 and i.e. cm., points to collect quite enough amount of measurements. In local agricultural regions conversely, it is inevitable to condense the measured net on the arable land.

In the chosen points for measurements, there must be drawn line till watershed beyond the men-made border – such as line of protective afforestation, profile of roads or border of arable land (field, pasture) and down, also till the arable lands or above mentioned man-made border, ravine thalweg. Below, in case of sharply straighten, line of flow is finishing at the section of slope sag (straighten) (ANONYMOUS, 1982).

Therefore, in the arable land already we have length (m) and inclination (%) by geomorhologic region. Next stage is calculation of erosion index of relief by the following equation according to WISCHMEIER and SMITH (1978)

$$LS = \left(\frac{X}{22.13}\right)^m (0.065 + 0.45S + 0.0065S^2) \tag{4}$$

where:
LS is the dimensionless factor of the relief
S - inclination of the slope (in %);

X - length of the slope (in m);
m - index of degree.

WISCHMEIER and SMITH (1978) gave the following m-index of degrees:
$m = 0.5$ - if inclination of slope is $>$ 5 %;
$m =$ 0,4 - if inclination is $\leq$ 5 and $>$ 3 %;
$m =$ 0.3 - if inclination is $\leq$ 3 and $\geq$ 1 %;
$m =$ 0.2 - if inclination is $<$ 1 %.

After finishing of the morphological works, for each region will be drown up diagram of erosion index of relies, with fixed interval, which for arable land is 0.25 and pasture - 1.0. Because, on the last classes fit small amount of measured parameter, therefore, we are correcting the left side of the diagram.

To compare the neighbor regions to each other, to determine true difference according the distribution of erosion potential of relief, criterion of Kolmogorov has been used (ANONYMOUS, 1982)

$$\lambda = \left(\frac{\sum n_1}{N_1} - \frac{\sum n_2}{N_2} \right) \sqrt{\frac{N_1 * N_2}{N_1 + N2}} \tag{5}$$

where:
$\sum n_1/N_1$ and $\sum n_2/N_2$ are accumulated frequencies (measurement) sum for each class, divided by the total amount of data of the first and second distribution (for the comparable regions).
If $\lambda \geq$1.36, difference among the regions is true.

Then the area of arable land and pasture will be calculated, in % by classes the erosion index relief. Area of P class lands is S_p, and calculated by the following equation,

$$S_p = \frac{n_p}{N} * 100\% \tag{6}$$

where:
n_p is the number of measurements by P class of the relief erosion index;
N is the total amount of measurements in geomorphological region on the arable lands and pasture.

Results are written in the table of the land distribution by geomorphological region.
Fort the calculation plant cover and management factor it is possible use method of USLE (WISCHMEIER and SMITH, 1978), but for large and small scale investigation it was calculated by the equivalent soil protection plant group.

All plants were divided the following groups:
1) Winter crop(wheat, barley, oats and etc.);
2) Spring crop, with height stalk hoe (maize, sunflower);
3) Low stalk hoe (sugar beet, folder root crops, melons, potato, tobacco);
4) Perennial grasses.

Besides, the separate area of the fallow is taken into account. These groups are devided by methods of soil till and agrotechnics:

a) Turn over a clod (traditional agrotechnique);
b) Cultivation with subsurface cultivator;
c) Industrial technology.
Total soils protection coefficient by agricultural plant group were calculated from the equation:

$$C = (C_1R_1 + C_2R_2 + ... + C_nR_n) * 100 \tag{7}$$

where:
C is the soil protection coefficient of the agricultural plants group;
$C_1, C_2, ..., C_n$ is the soil protection coefficient of the agricultural plants group in different periods, when soil protection of the plants didn't change;
$R_1, R_2, ..., R_n$ - is amount of erosion index of rain in % per relevant period. Finally, soil protection cartogram composed for investigation region or country.

It's advisable to separate regions from each other with 0.05 stages. Dimensionless erosion control factor (P) wasn't used.

Qualitative deflation and irrigation erosion danger of the reclamation fund lands of Georgia studied by the method of Moscow State University Problem Lab of Soil Erosion and Riverbed Processes (Anonymous, 1982).

3 Results and Analysis

For assessment of danger and cartography of lands of reclamation fund of Georgia, the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) and the Hydromechanical Model of Soil Erosion (Mirtskhoulava, 1978) were chosen. The Hydromechanical model of water erosion prognosis and USLE from the physical point of view are different from each other.
The model of Ts. Mirtskhoulava (Mirtskhoulava, 1978) is physically well grounded, but the map-making of territory by the USLE (Wischmeier and Smith, 1978) is relatively easy. The USLE is based on the experimental results of the soil erosion plots data. It's provided with corresponding coefficient of plants and agricultural management. By that USLE stands out from the other methods, because its practical use is easier.

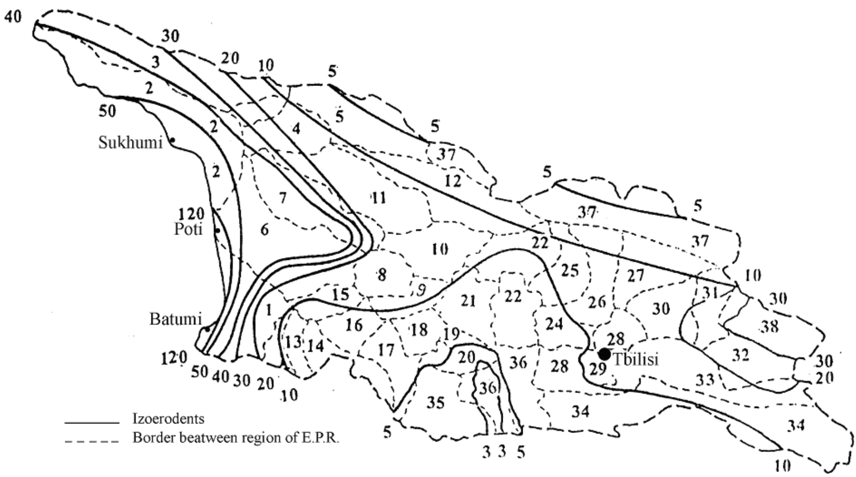
By investigations it was identified that erosion index of the rain (R_{30}) is directly proportional to soil loss (Wischmeier and Smith, 1978). Soil losses were calculated by the Mirtskhoulava (1978) model for each rain and erosion index of rain by the USLE. For investigation was taken environs of Akhaltsikhe, in southern Georgia. Length of slope was 150 m, inclination - 11 %. 21 years data of rainfall was used. Correlation coefficient between erosion index of rain and soil loss is 0.959; coefficient of determination is 0.920.

Carrying out tests (9 years) within the mountainous Adjara area, provide that annual potential soil loss calculated by the USLE is 10.5 % less than factual soil loss, relatively. But if soil loss is calculated only by foreseen of rains, which had washed out the soils. Difference between factual and calculated amount of soil losses is 1.77 %, because of the exactness of prognoses (forecast) increases 5-6 times (Gogichaishvili *et al.*, 2003).

The above mentioned research was carried out for estimation erosion danger lands of reclamation fund of Georgia by the USLE (Wischmeier and Smith, 1978).

On the basis of the data of all meteorological stations of Georgia, from 1936 to 1990 average annual erosion index of rain was calculated and the map of Georgia was composed (Fig. 1) (GOGICHAISH VILI and GORJOMELADZE, 1998).

Figure 1: Average annual erosion index of rain of Georgia.



On the second stage, on the basis of geomorphological division into districts (GOGICHAISH VILI and GORJOMELADZE, 1998) in the separate geomorphological region on the arable lands, perennial plantation, haymaking and pasture length and inclination of slope were measured according to the point-statistical method (LITVIN and MIRGORODSKAIA, 1976; LITVIN, 1976). After that, for different area the erosion index of relief (LS) was counted (WISCHMEIER and SMITH, 1978).
Geomorphological regions were divided by Kolmogorov criterion (ANONYMOUS, 1982). As for high erosion danger of the lands of the reclamation fund of Georgia indicated that from the separated 20 regions and subregions, in 13, 20-55 % of arable lands were arranged on the slopes with erosion index of relief (LS) which ranges from 5 to 10 unit.

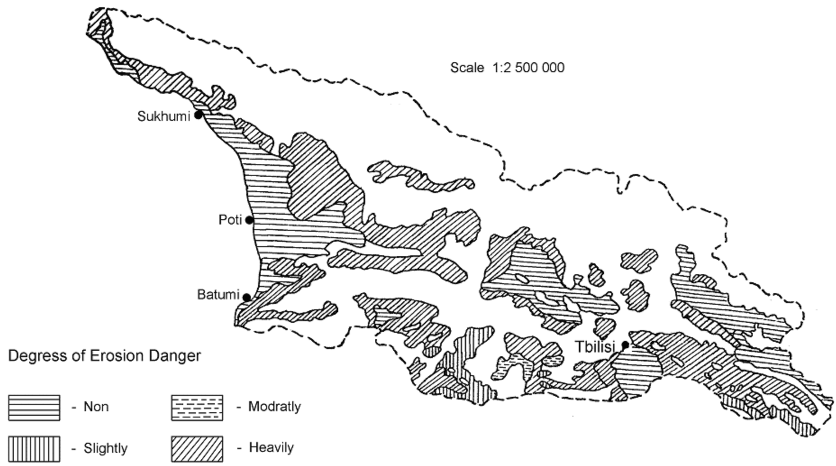
On the third stage, according to the private and fund materials erodibility of top layer soils of Georgia (K-factor) was determined which range from 0.8 to 3.8 t/ha (GOGICHAISHVILI and URUSHADZE, 2000).

In the next stage for 69 regions of Georgia their plant and agricultural management factor (C - factor) was calculated for winter and spring crop, maize, sunflower, potato, sugar beet, tobacco and perennial plantation. It was identified by investigations that in the most part of Georgia factor C varies from 0.419 to 0.661 (GOGICHAISH VILI and GORJOMELADZE, 1998). Based on above mentioned data and the USLE (WISCHMEIER and SMITH, 1978) for the lands of reclamation fund of Georgia annual soil loss was calculated.

Lands and territories where combination of natural conditions is producing possibility of prompt erosion in condition of economic use without methods of erosion control use (ZASLAVSKI, 1979). Soil tolerance was acceptance 2.5 t/ha per year and such territories are considered as non erosion danger lands or weak erosion danger, where potential soil loss is from 2.5 to 5.0 t/ha/year. Lands are of medium erosion danger when potential loss from this land is 5.0-10 t/ha/year and lands are heavy erosion danger where potential soil loss is more than 10 t/ha/year.

Potential soil loss for lands of reclamation fund of Georgia was calculated and composed a map in 1:500,000 scale (Fig.2).

Figure 2: Potential soil loss for lands of reclamation fund of Georgia.



Investigations ascertained that out of 103 thousand ha of Autonomous Republic of Abkhazia, 10 thousand ha (10 %) is of weak erosion danger (Table 2). Out of 50 thousand ha of the reclamation fund of A.R. of Adjara 41 thousands ha (82 %) are in condition of erosion danger. Among them 5 thousand ha (13 %) are weak erosion danger, 10 thousand ha medium and 26 thousand ha (63 %) heavy erosion danger. In South Osetia Autonomous District, out of the 64 thousand ha lands of the reclamation fund, 40 thousand ha (62.5 %) is in erosion danger condition. Among them 13 thousand ha (32 %) is weak erosion danger, 8 thousand ha (20 %) - medium and 19 thousand ha (48 %) - heavy erosion danger.

In Georgia, of 304 thousand ha (19 %) of the erosion danger lands of the reclamation fund, (19 %) is weak erosion danger, 80 thousand ha (5 %) - medium and 1194 thousand ha (76 %) - heavy erosion danger. Also 12 thousand ha of irrigated lands are erosion danger.

Table 2: Potential erosion and deflation danger of the agricultural and reclamation fund lands.

Administrative regions	*Lands of the potential danger of erosion (thousand ha / %)*							
	Agricultural lands			*Lands of reclamation fund*				
	total	*among them*		*total*	*among them*			*irrigation lands*
		arable lands	*mowing and pasture*		*weak*	*middle*	*heavy*	
Eastern Georgia	1070	283	787	964	276	42	646	12
	100	26	74	100	29	4	67	–
Western Georgia	500	425	75	430	–	–	430	–
	100	85	15	100	–	–	100	–
Regions without autonomous republics	1570	708	862	1394	276	42	1076	12
	100	45	55	100	20	3	77	–
Abkhazian A.R.	150	130	20	103	10	20	73	–
	100	87	13	100	10	19	71	–
Adjaria A.R.	50	45	5	41	5	10	26	–
	100	90	10	100	13	24	63	–
South-Osetia A. Region	64	34	30	4	13	8	19	–
	100	95	5	100	32	20	48	–
Total of regions of the Eastern Georgia	1134	317	817	1004	289	50	665	12
	100	28	72	100	29	5	66	–
Total of regions of the Western Georgia	700	600	100	574	15	30	529	–
	100	86	14	100	3	5	92	–
Total	1834	917	917	1578	304	80	1194	12
	100	50	50	100	19	5	76	–

Administrative regions	*Potential danger of deflation*							*Potential danger of irrigation*			
	Agricultural lands			*Lands of reclamation fund*				*Lands of reclamation fund*			
	total	*among them*		*total*	*among them*			*total*	*among them*		
		arable lands	*mowing and pasture*		*weak*	*middle*	*heavy*		*weak*	*middle*	*heavy*
Eastern Georgia	585	193	392	505	216	223	66	137	128	9	–
	100	33	67	100	43	44	13	100	93	7	–
Western Georgia	–	–	–	–	–	–	–	33	26	7	–
	–	–	–	–	–	–	–	100	79	21	-
Regions without autonomous republics	585	193	392	505	216	223	66	170	154	16	–
	100	33	67	100	43	44	13	100	91	9	–
Abkhazian A.R.	7	–	7	–	–	–	–	10	10	–	–
	100	–	100	–	–	–	–	100	100	–	–
Adjaria A.R.	2	–	2	–	–	–	–	4	3	1	–
	100	–	100	–	–	–	–	100	75	25	–
South-Osetia A. Region	15	7	8	5	4	1	–	–	–	–	–
	100	–	–	100	80	20	–	–	–	–	–
Total of regions of the Eastern Georgia	600	200	400	510	220	224	66	137	128	9	–
	100	–	–	100	43	44	13	100	93	7	–
Total of regions of the Western Georgia	9	–	9	–	–	–	–	47	39	8	–
	100	–	100	–	–	–	–	100	83	17	–
Total	609	200	409	510	220	224	66	184	167	17	–
	100	33	67	100	43	44	13	100	91	9	–

510 thousand ha of the reclamation fund are deflation danger. Among them 220 thousand ha (43 %) is concern to weakly deflation danger (Table 2), 224 thousand (44 %) - middle and 66 thousand (13 %) - heavy deflation.

As deflation danger is determined only by the deflation index of the wind, above mentioned estimation is qualitative and approximate (Anonymous, 1982). Estimation of erosion danger of irrigation land is based on the quantitative forecast method.

In western Georgia out of 137 thousand ha lands of reclamation fund, 128 thousand ha (93 %) is weak erosion danger and 8 thousand ha (17 %) - medium erosion danger. Using the of above mentioned method, heavy erosion danger area was not obswerved.

According to the separate regions of Georgia, in case of producing the traditional agricultural crops and having carried out the erosion processes, the use of the USLE gives an opportunity to control ecological condition on the agricultural lands of reclamation fund of Georgia.

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Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 107, No. 1, 2006, pages 95–101

Buchbesprechungen

William Gamboa; 2005

Producción agroecológica: una opción para el desarrollo del cultivo del Chayote (*Sechium edule* /Jacq./ Sw.**)**

219 Seiten mit zahlreichen Abbildungen, Tabellen, Fotos und Zeichnungen, Editorial de la Universidad de Costa Rica, 2005, ISBN: 9977-67-911-8. Preis: 15,00 €.

Die Chayote, Güisquil oder Pear Squash hat in den vergangenen zwei Jahrzehnten auch die Märkte außerhalb des hispanischen Kontinentes erobert. Dazu trugen sowohl die gute Haltbarkeit und Transporteigenschaften als auch die vielfältigen kulinarischen Verwendungsmöglichkeiten von Früchten, Wurzeln und Blättern dieses ausdauernden tropischen Kürbisgewächses bei. Eine umfassende wissenschaftliche Abhandlung über Sechium edule fehlte bisher auf dem internationalen Büchermarkt. In jahrelangen akribischen Literaturrecherchen, Feldarbeiten und Forschungsstudien erarbeite GAMBOA ein übersichtlich gestaltetes, reich bebildertes und instruktives Nachschlagewerk. Die Monographie ist in vier Teile gegliedert. In den ersten drei Kapiteln werden Herkunft, Taxonomie, Botanik und die ökophysiologischen Ansprüche von Chayote ausgewogen und inhaltsreich dargestellt. Das Kapitel 4 ist dem Auftreten von Krankheiten, Schädlingen und Unkräutern gewidmet. In den folgenden beiden Kapiteln werden praktische Erfahrungen zum intensiven Chayoteanbau aus den weltweit wichtigsten Anbauregionen zusammengefasst. Der Exkurs führt von den möglichen Methoden der Bodenbearbeitung, über die Pflanzgutgewinnung, Pflanz - und Stützsysteme, die Düngung, den integrierten Pflanzenschutz, die Bewässerung bis hin zu den Erntemethoden, dem Nacherntemanagement, der Kommerzialisierung und dem betriebswirtschaftlichen Ergebnis. Der vierte Teil beinhaltet fünf Kapitel, die sich den Möglichkeiten und Hemmnissen des ökologischen Anbaues von Chayote stellen. Damit beschreitet der Autor absolutes Neuland für diese Kultur. Anhand von eigenen Untersuchungen und Studien werden züchterische und sortenspezifische Charakteristika dieser Spezie aufgeführt, nachhaltige Anbaupraktiken diskutiert, der organische Anbau von Chayote vorgestellt, faire Handelspraktiken diagnostiziert und soziokulturelle Besonderheiten der exportorientierten Chayoteanbauer beschrieben. Die zusätzlichen Daten und Beispiele im Anhang runden in gekonnter Weise dieses faktenund informationsreiche Werk für Wissenschaft und Praxis ab.

J. Pohlan, Bonn

Franz Alt, Rosi Gollmann und Rupert Neudeck; 2005

Eine bessere Welt ist möglich
Ein Marshallplan für Arbeit, Entwicklung und Freiheit

Riemann Verlag, München, ISBN 3-570-50069-1, 320 Seiten,19,– €.

Ein Marshallplan für Zwei Drittel der Menschheit, wäre das möglich?

Die drei Autoren, mit der Situation, gerade der Krisenregionen der Welt, gut vertraut fordern dies und sehen dafür auch Möglichkeiten. Das Buch mit den Kapiteln "Entwicklungspolitik ist Friedenspolitik" (Franz Alt), "Praktische Entwicklungszusammenarbeit mit menschlichem Gesicht" (Rosi Gollmann) und "Von Lügen, Lobbys und echter Hilfe" (Rupert Neudeck) beschreibt Situationen, die größtenteils bekannt sind und doch nicht so wahrgenommen werden. Schaffen wir nur noch größere Spenden bei Naturkatastrophen und wollen das tägliche Elend nicht mehr sehen? Dabei wird von allen dreien gut beschrieben, was erreicht werden kann, wenn wir es denn nur wollen. Arme und Reiche müssen sich ent-wickeln und die europäischen Länder sind dabei an ihr wohl verstandenes Eigeninteresse erinnert, siehe die Situation in den spanischen Enklaven in Afrika. Die Regierungschefs der EU-Staaten haben den Anstieg der Entwicklungshilfe festgeschrieben und ein Viertel der europäischen Hilfe könnte durch bessere Koordination sinnvoller ausgegeben werden (Die Zeit, 20.10.2005, S. 40). Die drei Autoren beeindrucken durch ihr Engagement, aber auch durch ihre Vorschläge und ihre Zuversicht in eine bessere Welt. Nicht Vorschriften, sondern Köpfe, die handeln sind gefordert. Dabei ist der Respekt vor der Würde des Menschen wichtig und die betroffenen Menschen müssen ihre Prioritäten selbst setzen. Das Buch berührt und ist nicht nur denjenigen, die sich schon mit Entwicklungshilfe befassen, sondern gerade auch Politikern zum Lesen wärmstens empfohlen.

H. Hemann, Witzenhausen

Wyk, Ben-Erik van; 2005

Handbuch der Nahrungspflanzen. Ein illustrierter Leitfaden

Stuttgart (Wissenschaftliche Verlagsgesellschaft) 2005, 479 S. mit 1009 Farbfotos. ISBN 3-8047-2246-6, Preis 39.- €

Food Plants of the World - identification, culinary uses and nutritional value

Pretoria (BRIZA Publications) 2005, 480 pp. ISBN 1-875093-56-7, price 39.- €

Der sehr produktive Autor hat schon wieder ein Werk abgeliefert - diesmal gleich in zwei Sprachen. Die englische Version ist das Original, deutsche Übersetzung: Friedel Herrmann. Das Ergebnis ist überzeugend. Es liegt ein Kompendium vor, das neben einer Einleitung (36 Seiten, geographische Herkunft, Charakterisierung der wichtigsten Nahrungspflanzengruppen) im Hauptteil (S. 36 - 391) die wichtigsten Nahrungspflanzen beschreibt und ausführlich mit Farbfotos illustriert (*Abelmoschus esculentus* bis *Ziziphus jujuba*, insgesamt 354 Pflanzen!). Es ist damit eines der wenigen Werke, die die Vielfalt der Kulturpflanzen eindrucksvoll demonstrieren. Zu jeder Pflanze (meist Art, aber zuweilen auch infraspezifische Gruppe) gibt es eine Beschreibung, Bemerkungen zu Herkunft und Geschichte, zu den verwendeten Teilen, zur Kultur, zur Verwendung und zum Nährstoffgehalt. Gelegentlich folgen noch Anmerkungen.

Der Rezensent hat die Daten stichprobenartig geprüft und insgesamt für gut befunden. Die Abbildungen sind meist hervorragend. Bedauerlich sind einige Fehlbestimmungen. So ist 'Witloof' nicht *Cichorium endivia*, obwohl gelegentlich auch "Endivie de Witloof" genannt, sondern *C. intybus*. Unter *Lathyrus sativus* ist *L. latifolius* als "Gartensorte" abgebildet. Auch die Samen gehören nicht zur beschriebenen Art. Bei *Lupinus albus* handelt es sich um eine andere Art. *Ruta graveolens* (Abb. rechts unten) ist eine typische *Ruta chalepensis*. Die botanischen Namen (mit Autoren) sind überwiegend korrekt geschrieben. Kleinere Fehler wie *Gossypium arboretum* = *G. arboreum* oder *Kaempferia galangal* = *K. galanga* kommen vor.

Den Abschluß des Werkes bilden nahrungsmittelchemische Erläuterungen, eine alphabetische Kurzübersicht zu den Nahrungspflanzen (ca. 800 Sippen), ein Glossar und ein Register der wissenschaftlichen und Trivialnamen. Das Buch verdient eine weite Verbreitung.

K. Hammer, Witzenhausen

Jansen, P.C.M. & Cardon, D. (Editors); 2005

Plant Resources of Tropical Africa 3. Dyes and tannins

PROTA Foundation, Wageningen, Netherlands / Backhuys Publishers, Leiden, Leiden, Netherlands / CTA Wageningen, Netherlands. 216 pp. ISBN 90-5782-159-1 (book only), price €25 (Industrialized countries). €12.50 (Developing countries). ISBN 90-5782-160-5 (book + CD-Rom), price €32 (Industrialized countries), €16 (Developing countries).

Ressources végétales de l'Afrique tropicale 3. Colorants et tanins (Transduction)

Fondation PROTA Wageningen, Pays-Bas/CTA, Wageningen, Pays-Bas. 238 pp. ISBN 90-5782-163-X (livre seul), price €25 (Pays industrialisés), €12.50 (Pays en développement). ISBN 90-5782-164-8 (livre et CD-Rom), price €32 (Pays industrialisés), €16 (Pays en développement).

Treatments covering the diversity of African useful plants are still very rare. Therefore, this volume is an excellent source of information. This can be demonstrated e.g. by comparing the species included with those of the world treatment of P. Hanelt (ed.), 2001., Mansfeld's Encyclopedia of Agricultural and horticultural Crops. The following candidates could be found for possible new inclusion into that compilation or confirmation of species only occasionally mentioned:

- *Arnebia hispidissima* (Sieber ex Lehm.) DC. (Boraginaceae)
- *Bruguiera gymnorhiza* (L.) Savigny (Rhizophoraceae)
- *Craterispermum laurinum* (DC.) Benth. (Rubiaceae)
- *Craterisprmum schweinfurthii* Hiern (Rubiaceae)
- *Euclea divinorum* (Ebenaceae)
- *Ficus glumosa* Delile (Moraceae)
- *Flemingia grahamiana* Wight et Arn. (Papilionaceae)
- *Impatiens tinctoria* A. Rich. (Balsaminaceae)
- *Indigofera longiracemosa* Boivin ex Baill. (Papilionaceae)
- *Lannea barteri* (Oliv.) Engl. (Anacardiaceae)
- *Pauridiantha rubens* (Benth.) Bremek. (Rubiaceae)
- *Psilanthus ebracteolatus* Hiern (Rubiaceae) - can be successfully hybridized with Coffea arabica!
- *Pterocarpus angolensis* DC. (Papilionaceae)
- *Pterolobium stellatum* (Forssk.) Brenan (Caesalpinaceae)
- *Rathmannia longiflora* Salisb. (Rubiaceae)
- *Xylocarpus granatum* J. Koenig (Meliaceae)

After finishing the edition of the well Known PROSEA, PROTA (Plant Resources of Tropical 'Africa) Makes great progress. From the 16 volumes (apart from the precursor) now already the second appeared. Species which harvest dyes and tannins are treated in alphabetical order according to accepted Latin names. For each entry the following data are provided: Protologue, Family, Chromosome number, Synonyms, Venacular names, Origin and geographical distribution, Uses, Production and international trade, Properties, Adulterations and substitutes, Description, Other botanical information, Anatomy, Growth and development, Ecology, Propagation and planting, Mangement, Diseases and pests, Harvesting, Yield, Handling after harvest, Genetic resources, Breeding, Prospects, Major references, Other references, Source of illustrations and authors. For the important species figures and distribution maps are shown.

The volume is completed by a list of plants providing dyes and tannins but with other primary use (8 pages), literature (pp. 177 - 205, astonishingly the above mentioned "Mansfeld" is not included), and indices of scientific and vernacular plant names. A very useful and comprehensive volume of Afrika's plant dyes and tannins.

K. Hammer, Witzenhausen

Journal of Agriculture and Rural Development in the Tropics and Subtropics
Volume 107, No. 1, 2006, pages 99–101

Kurznachrichten

A new Master Programme MSc International Food Business and Consumer Studies

Objectives

The politics of food in society, involving manufacturers, retailers, consumers and health professionals, are complex and continually evolving. This program enables its students to take on responsible tasks in national and international enterprises in the food business, as well as in food certification organisations. In particular, they are qualified

- to manage complex processes in enterprises in food industries and food trade as well as farms
- to develop and market food products and related services according to the needs of different consumer groups.

The graduates, with their flexibility of thinking and wide range of knowledge and skills, are proving increasingly attractive to employers. Graduates are qualified for further postgraduate studies, esp. PhD programs.

Course Structure

The postgraduate programme is characterised by a multidisciplinary approach at the interface between agriculture, food business and consumer science, within an international context. The MSc 'International Food Business and Consumer Studies' is a joint venture of two German Universities: The University of Kassel in Witzenhausen (Organic Agricultural Sciences) and the University of Applied Sciences Fulda (Nutritional, Food and Consumer Sciences).

One semester abroad is recommended. Project partners, particularly in Middle and Eastern Europe, are available to the students. The regular duration of study is four semesters (2 years; 120 ECTS Credits).

Admission Requirements

The programme aims at graduates, which hold a Bachelor's, or equivalent degree in the field of consumer science, nutrition, food science, food technology or agricultural science. Candidates with a background in economics and related fields possess appropriate knowledge and skills at degree standard in fields related to food and agricultural economics/business.
Applicants whose first language is not English should be able to demonstrate a satisfactory level of spoken and written English (TOEFL 61 - Internet based)

Application deadline

EU Nationals: August 1
Non EU Nationals: Students need to apply by March 1 to allow time for registration, financing and visa-formalities.

For further information please contact:

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Announcement

Tropentag 2006

Prosperity and Poverty in a Globalized World -
Challenges for Agricultural Research
October 11 - 13, 2005, University of Bonn, Bonn, Germany

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 Tropentag 2006 will be held in Bonn. 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

Programme Coordination

- ◇ Prof. Dr. Klaus Becker
- ◇ Dr. Christian Hülsebusch
- ◇ Dr. Eric Tielkes

on behalf of the Board of the Centre for Agriculture in the Tropics and Subtropics.

Further Information:

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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, vector formats, postscript .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

Manuscripts and communication should be addressed to:
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April 2004