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Intensification of rain-fed groundnut production in North Kordofan State, Sudan

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Abstract

The main objective of this study was to evaluate intensification pathways for groundnut production in the marginal rain-fed environment of North Kordofan State, Sudan. The effect of intensification on yields was assessed in three different experiments. In the first experiment, the treatments were organised according to increasing level of intensification from the traditional production package to the improved production package (the ladder experiment). The complete improved package in the ladder approach consisted of increased density, new variety, seed priming, micro-dosing (0.6 g NPK per pocket) and mulching. Three levels of mulching and two levels of intensification constituted the second experiment (mulching experiment), while the third was an on-farm experiment involving 20 farmers testing two levels of intensification (on-farm experiment). The average yield increases were 75, 61, and 32 %, from the ladder, mulch and on-farm experiments, respectively. Results from the ladder experiment showed that farmers' gross margin increased by 83 % compared to traditional practices. Resource limited farmers can increase yield by 18 % and gain 25 % additional cash incomes by only adopting increased plant density. As farmers differ in their wealth status, they can choose low-cost, low-risk components of the technological package whereas farmers with more access to resources can achieve high cash incomes by adopting the complete improved production package. There was no clear effect of mulching on yields in these experiments.

Keywords: plant density, variety, seed priming, micro-dosing, mulching, profitability

1 Introduction

Crop production in the sandy rain-fed areas of North Kordofan State in Sudan is mainly practised by smallholder, resource-limited farmers who constitute 75–80 % of the population. The environment is characterised by low and erratic seasonal rainfalls, short growing periods, and poor soil conditions with very low extractable phosphorus (4 mg / 100 g), low carbon (0.056 %) and low nitrogen (0.03 %) due to continuous cultivation. Kordofan State is generally classified as one of the most vulnerable areas of Sudan due to frequent droughts (NAPA, 2007). Average yield for groundnut is estimated at 184 kg ha^{-1} (NKSMARD, 2014). Farmers expand cultivated areas to increase production in order to attain food security and improve their livelihoods. Agriculture is practiced without improved technologies such as the use of fertilisers, irrigation, water conservation or improved high yielding and disease resistant varieties. In West Africa, crop and soil management research has shown that the introduction of high yielding and disease resistant improved crop varieties accompanied by appropriate crop management practices can more than double sorghum and pearl millet grain yields while reducing soil and organic carbon depletion (Bagayoko *et al.*, 1996; Coulibaly *et al.*, 2000). In Sudan, Elobeid Research Station has recommended improved high yielding and disease resistant crop varieties and crop husbandry practices for increasing the yield of the major crops grown on sandy soils

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under marginal rain-fed conditions. Yield of groundnut crop was increased by 20 % due to improved varieties (Abdalla & AlAhmedi, 1997). Elements of the production package were individually evaluated in groundnut cultivation using the ‘minus one’ trial technique. The study showed that farmers should plant early in order to obtain high yields. However, since that study, new technologies such as seed priming and NPK fertiliser micro-dosing have been recommended (Osman & Elamin, 2000). Therefore, there was a need to test and evaluate the complete production package as well as the effect of each component individually. The approach used in this study was the ladder approach in which the treatments are ordered according to increasing levels of intensification. It was expected that yields increase as intensification levels increase, but so will the cost and associated risks. Farmers can choose different levels of intensification depending on the available resources. As farmers get more resources and confidence in the technologies, they can “climb” the intensification ladder and reap more benefits. The ladder approach has previously identified low-cost, low-risk technologies for food crops in West Africa that could be adopted by resource limited and wealthy farmers (Aune & Bationo, 2008). Resource-efficient technologies can make it more appealing for farmers to intensify production rather than to clear land for cultivation. The study assessed if increasing levels of intensification can increase yields and gross margins in groundnut production under the marginal rain-fed environment of North Kordofan State, Sudan.

2 Materials and methods

Studies were conducted during the cropping seasons of 2013/2014 and 2014/2015 on sandy soil at Elobeid Research Station farm (30°14′13.230″ E; 13°12′36.801″ N) in Elobeid City, North Kordofan State, Sudan. As shown in Table 1, the treatments were organised according to increasing levels of intensification. Treatment 1 represents farmers’ own production package, while treatment 6 represents a complete improved production package. In treatments 2–5, one component of farmers’ own production package was replaced by a component of the improved package in ascending order.

Farmers’ current production package consisted of a popular variety (Barberton), conventional spacing (40 cm × 40 cm) and single seed per hole corresponding to 62,500 seeds ha^{-1}, no priming, no micro-dosing and no mulching, while the complete improved production package consisted of one improved variety (Gubeish), increased density (60 cm × 20 cm) and two seeds per hole corresponding to 166,666 seeds ha^{-1}, seed priming, NPK micro-dosing (0.6 g / hole) and sorghum straw mulching (0.5 ton ha^{-1}). The Gubeish and the Barberton varieties mature in 85 and 100 days, respectively and the yield is about 20 % higher for Gubeish compared to Barberton. Seed priming consists of soaking the seeds in water for 8 hours, followed by air-drying at room temperature for one hour before being sown. The treatments were laid out in a randomized complete block design (RCBD) with four replications.

Simultaneously, a second experiment was carried out to test the effect of mulching on groundnut under rain-fed conditions. This experiment was a 3 × 2 factorial, consisting of three mulching levels (zero, 0.5 ton ha^{-1}, and 1 ton ha^{-1}) and two production packages (farmer practice and improved package). The improved production package included seed priming, micro-dosing of 0.6 g NPK fertiliser per planting pocket and the improved variety (Gubeish), while the farmers’ package was without these applications. Treatments were laid out in a RCBD with four replications and a plot size of 6 rows, each 5 m long. The fertiliser used was NPK 15-15-15, applied with the seeds at planting as a micro-dose of 0.6 g per hole. Mulching was applied before planting by spreading sorghum straw on the soil. The data collected included vigour scores based on visual observation after two and four weeks from seeding 100-seed weight, shelling percentage, pod and hay yields.

The on-farm trials included 20 farmers each in three villages where the improved package tested consisted of an improved variety, NPK micro-dosing of 0.6 g per pocket and mulching. The plot size was 10 m × 10 m for each treatment.

Table 1: *Components of the production package using the ‘plus trial’ technique.*

Treatments	*Elements of the package*				
1: Farmers’ own package	Conventional density	Local variety	No seed priming	No micro-dosing	No mulching
2	Increased density	Local variety	No seed priming	No micro-dosing	No mulching
3	Increased density	Improved variety	No seed priming	No micro-dosing	No mulching
4	Increased density	Improved variety	Seed priming	No Micro dosing	No mulching
5	Increased density	Improved variety	Seed priming	Micro dosing	No mulching
6: Complete improved package	Increased density	Improved variety	Seed priming	Micro dosing	Mulching

Table 2: *Effect of improved production package on yield (kg ha^{-1}) and yield components of groundnut and gross margin in Sudanese Pounds† (SDG ha^{-1}) combined over 2013/2014–2014/2015 cropping seasons.*

Treatment	*Stand* 1000 ha^{-1}	*Pod yield*	*Hay yield*	*Gross margin SDG (Pod + hay)* ‡	*100 seed weight* (g)	*Vigour*	*Shelling %*
Farmers' package (FP)	42 ^{c}	707 ^{c}	958 ^{b}	3962 ^{c}	34 ^{bc}	4 ^{a}	64 ^{b}
Increased density (ID)	71 ^{b}	836 ^{bc}	1132 ^{b}	4967 ^{bc}	32 ^{c}	3 ^{b}	67 ^{ab}
ID+Improved variety (IV)	78 ^{ab}	942 ^{bc}	1201 ^{b}	5733 ^{abc}	35 ^{b}	3 ^{b}	67 ^{ab}
ID+IV+priming (P)	92 ^{a}	1035 ^{ab}	1542 ^{a}	6577 ^{ab}	36 ^{ab}	2 ^{c}	69 ^{a}
ID+IV+P+Micro-dose (M)	83 ^{ab}	1080 ^{ab}	1563 ^{a}	6565 ^{ab}	34 ^{bc}	2 ^{c}	70 ^{a}
ID+IV+P+M+Mulching (M)	66 ^{b}	1236 ^{a}	1708 ^{a}	7258 ^{a}	38 ^{a}	2 ^{c}	69 ^{a}
SE	6 **	90 **	62 **	607 **	0.8 **	0.2 **	1 **
CV %	23	26	13	29	7	29	5

Figures with different letters are significantly different at 0.05 probability level. Vigour score from 1 to 5 with 1 as highest score at harvest.
† 1 SDG = 0.045 Euro (03/2018)
‡ Prices: Prices were obtained from local market and were 6.7 SDG kg^{-1} and 0.8 SDG kg^{-1} for groundnut and ground hay respectively. Total variable cost were 1,450 SDG ha^{-1} for farmers practice.

The data were analysed using MSTATC software (MSTAT, 1993). The gross margin was calculated by deducting the variable costs (land cleaning, seed dressing, seed price, fertiliser cost, labour cost, cost of bags, transportation cost and land rental costs) from the total cash income (pods and hay). The production costs were taken from the annual agricultural survey report (North Kordofan State Ministry of Agriculture and Rural Development, 2014). The fertiliser cost was added in the micro-fertiliser treatment based on the amount of fertiliser applied.

3 Results

3.1 Ladder experiment

Over the two seasons in the ladder experiment, groundnut seedling vigour, crop establishment, pod yield, hay yield, 100 seed weight, and shelling percentage were enhanced each time an improved element was added to the production package (Table 2). Yield increments of 18, 33, 46, 53, and 75 % were observed due to the ascending effects of plant density, improved variety, seed priming, NPK fertiliser micro-dosing and mulching, respectively. The highest pod yield (1,236 kg ha^{-1}) obtained from the complete package was significantly higher than farmers' package with a pod yield of 707 kg ha^{-1}. The treatment including micro-dosing was significantly higher than farmers practice. Increased plant density alone increased yield by 18 %, while the improved variety increased yield by an additional 13 %. The highest hay yield and shelling percentage were also recorded under the complete improved technological package. Shelling percentage, which is indicative for seed filling, was highest in the treatment including fertiliser micro-dosing. The yield increase with increasing level of intensification is a result of improved stand, superior seedling vigour and improved grain filling. The gross margin increased as new technologies were added and the highest return was attained from the complete package (Table 4). The gross margin increased by 83 % from the lowest to the highest intensification level, representing an additional revenue of 3,296 SDG ha^{-1} ($p < 0.01$).

3.2 Mulching experiment

The experiment with three mulch levels and two production packages (improved and farmers' package) showed that the improved package performed better than farmers' package, while there was no effect of mulching. Over the two cropping seasons, the improved production package enhanced seedling vigour, pod yield, hay yield, 100-seed weight and stand at harvest compared to farmers' package (Table 3). Pod and hay yields were improved by 61 and 50 %, respectively. Mulching as an individual component did not significantly improve yield and yield components, and its effect was only significant on plant vigour which was significantly better at the highest mulching treatment. The gross margin was improved by 80 % with the introduction of the improved technological package; this improvement was not, however, due to mulching.

3.3 On-farm trials

Results from the on-farm trials showed a significant improvement in pod and hay yields when farmers adopted the improved production package with 0.5 ton ha^{-1} sorghum straw mulching (Table 4). Pod yield increased by 32 % and hay yield by 19 % due to the improved production package. Gross margin increased by 30 % as the result of the improved package, with a net gain of 2,778 SDG ha^{-1} (125 Euro).

Table 3: *Effect of mulching and improved package on yield and yield components of groundnut (mulching experiment), combined over 2013/2014 and 2014/2015 cropping seasons.*

Treatment	*Farmers' package*	*Improved package*	*Mean*
Pod yield (kg ha^{-1})			
Zero mulching	708 ^{bc}	1070 ^{a}	889
Mulching (0.5 ton)	644 ^{c}	932 ^{ab}	788
Mulching (1 ton)	624 ^{c}	1168 ^{a}	896
Mean	658	1057	
SE	51 **		
Hay yield (kg ha^{-1})			
Zero mulching	771 ^{b}	1276 ^{a}	1024
Mulching (0.5 ton)	903 ^{b}	1390 ^{a}	1146
Mulching (1 ton)	952 ^{b}	1274 ^{a}	1113
Mean	875	1313	
SE	63 **		
Gross margin (SDG ha^{-1})			
Zero mulching	3,817 ^{bc}	6,182 ^{a}	4,999
Mulching (0.5 ton)	3,098 ^{c}	4,947 ^{ab}	4,023
Mulching (1 ton)	2,600 ^{c}	6,035 ^{a}	4,318
Mean	3,172	5,722	
SE	359 **		

Figures with different letters are significantly different at 0.05 probability level.
Vigour score from 1 to 5 with 1 as highest score at harvest.

Table 4: *Pod yield, hay yield and gross margin (GM) in SDG ha^{-1} from on-farm trials.*

Treatment	*Season 2013/2014*		*Season 2014/2015*		*Combined over locations and seasons*		
	Pod yield (kg ha^{-1})	*Hay yield* (kg ha^{-1})	*Pod yield* (kg ha^{-1})	*Hay yield* (kg ha^{-1})	*Pod yield* (kg ha^{-1})	*Hay yield* (kg ha^{-1})	*GM (Pod + hay yield)*
Farmers' package + seed priming	1,428 ^{b}	885 ^{b}	1,224 ^{b}	3,937	1,275 ^{b}	3,174	9,159 ^{b}
Improved package + mulching (0.5 ton ha^{-1})	1,916 ^{a}	1,470 ^{a}	1,611 ^{a}	4,546	1,687 ^{a}	3,777	11,937 ^{a}
SE	105**	175**	22**	297	19**	223	235**
CV	9	21	12	54	11	57	20

Figures with different letters are significantly different at 0.05 probability level. Vigour score from 1 to 5 with 1 as highest score at harvest.

4 Discussion

Groundnut production in the sandy, rain-fed areas of North Kordofan State is characterised by very low yields (185 kg ha^{-1}) (NKSMARD 2014). For this reason, farmers cultivate large areas as a strategy to sustain, and increase cash income. North Kordofan is classified as the most vulnerable area to climate change in Sudan and there is a need to develop and promote the use of improved technological packages that can sustain groundnut production and productivity. The yield increasing effect of combining seed priming and fertiliser micro-dosing as compared to farmers practice has previously been shown in groundnut, cowpea, pearl millet and sorghum in the drylands of Africa (Osman & Aune, 2011; Aune & Osman, 2011; Maman *et al.*, 2000). In this study, groundnut pod yield was significantly increased due to the introduction of different components of an improved technological package. The yield increase observed in the improved package was 75 % in the experiment with increasing levels of inputs, 61 % in the experiment with three mulch levels, and 32 % in the on-farm experiment. These yield records show that there is a consistent yield increase with the adoption of improved groundnut packages. By increasing yields it is also likely that the need for clearing new land for cultivation could be reduced. The tendency of the farmers to avoid land clearing as they adopt more intensive management technologies has been shown in West Africa (Aune & Bationo, 2008; McCalla, 1999). Thus, the transformation of subsistence-oriented farming to small-scale commercial farming units can be achieved by adopting improved technologies. Wealthier farmers could adopt the full package while resource-limited farmers can make use of the least costly technologies in the intensification ladder. Results from the ladder study showed that the gross margin can be increased up to 83 % (3,296 SDG ha^{-1}). This can be seen as a result of combining all the yield enhancing technologies.

Mineral fertiliser in Sudan has been mainly used in the irrigated sector, but there is now a national recommendation to use micro-dosing in dryland crops as well. However, availability of mineral fertiliser is still a problem. Resource-limited farmers with little chances of accessing inputs (notably fertilisers and mulching materials) can achieve an increase in yield of 18 % and gain 25 % additional gross margin (equivalent to 1005 SDG ha^{-1}), only by applying the recommended spacing and planting density (Table 2). High plant density has been reported to be crucial for increasing yield of rain-fed groundnut grown in the sandy soils of Sudan (Osman & Sid Ahmed, 1993). Farmers can gain 45 % additional revenue, equivalent to 1771 SDG ha^{-1}, by adopting recommended planting density and the improved groundnut variety. They can further improve yields by 46 % by adding seed priming to the previous package, increasing the gross margin by 66 %, equivalent to 2,615 SDG ha^{-1}. Seed priming is a method accessible to the farmers as no external inputs are needed. The effect of mulching was variable in these experiments. In the ladder experiment, mulching increased yield while this effect was not apparent in the experiment with increasing levels of mulching. Though no clear effect of mulching was observed in these experiments, the effect of mulch on improving soil quality is well documented (Buerkert *et al.*, 2002). High cost of sorghum straw due to competitive use of biomass as fodder, fuel and building material has been reported as a constraint limiting the use of sorghum or millet straw for mulching in West Africa (Lal, 2007). Grazing pressure is also high in the off-season, making it difficult to retain mulch on farmers' fields. There is a need to develop new approaches to ensure more mulch retention. One simple approach could be to cut the straw at 10-20 cm above ground level, leaving the bottom part. Introducing mulch-producing trees such as *Guiera senegalensis*, *Piliostigma reticulatum*, *Acacia senegal* and *Faidherbia albida* is another approach (Lahmar *et al.*, 2012). The use of mulch producing trees may be complemented with improved rotations including leguminous crops.

5 Conclusions

This study has shown that farmers can significantly increase groundnut yields and returns by adopting (parts of) a new technological package. The yield and gross margin revenue increased with increasing levels of intensification. Adopting the complete technological package gave 83 % higher gross margin than farmers' package. Resource-limited farmers can choose low-costs, low-risk components of the technological package whereas farmers with better access to resources can adopt the complete technological package.

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