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Effect of integrated agronomic management practices on yield and yield components of groundnut in Abergelle, Tigray, Ethiopia

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Poor soil fertility, moisture stress, and shortage of early maturing varieties are the major groundnut production constraints in the study area. This study was executed to evaluate the effect of Diammonium phosphate (DAP) and gypsum application, tied ridging and supplementary irrigation on groundnut production. The experiment was laid out in a Randomized Complete Block Design with three replications in two sites. DAP as a source of phosphorous and gypsum as source of calcium were applied at planting and pod setting stages, respectively. While tied ridging and supplementary irrigation were applied at early flowering and during cessation of rainfall, respectively. Phenological, yield, and yield components data were recorded. Analysis of variance indicated that the integrated agronomic management options showed a significant positive effect on plant height, pods per plant, dry biomass weight, dry pod weight, kernel seed yield and 100-seed weight of groundnut at both experimental sites. Between both experimental sites, the highest kernel yield (980 kg/ha) was recorded when supplementary irrigation + tied ridge + fertilizer were practiced while the lowest yield (290 kg/ha) was recorded in the control.

Key words: Agronomic practices, yield and yield components, moisture stress, groundnut.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is the sixth most important oilseed crop in the world. It is used as oilseed, food and animal feed all over the world (Upadhyaya et al., 2006). Besides its function as a food and feed, the crop is also considered as a component of rotation in many countries (Gbèhounou and Adengo, 2003). The multiple use of the groundnut plant makes it an excellent cash crop for domestic markets as well as for foreign trade in several developing and developed countries. The oil content of the crop has been well documented. As the world's 4th most important source of edible oil, groundnut seed contains high quality edible oil (50%), easily

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digestible protein (25%) and 20% carbohydrates (Bhatia et al., 2006).

Groundnut is grown on 26.4 million ha worldwide with a total production of 37.1 million metric ton and an average productivity of 1.4 t/ha (FAO, 2003). Developing countries constitute 97% of the global area and 94% of the global groundnut production (Nigam et al., 2004). The production of groundnut is concentrated in Asia and Africa, with 56 and 40% of the global area and 68 and 25% of global output, respectively (Nigam et al., 2004).

Groundnut is relatively recent to Ethiopia. It was introduced to Northern Ethiopia by the Portuguese in the 17th century, and later through Arab influence to the South-eastern part of the country (Brereton, 1980). It grows in the warmer regions of eastern and northern Ethiopia. The total area cultivated to groundnut in Ethiopia was estimated to be 41,578.79 ha (CSA, 2010). Its productivity is restrained by drought stress, use of low levels of inputs by smallholder farmers in marginal dry land areas. According to CSA's (2010) agricultural sample survey, the productivity of groundnut in Ethiopia is 1.197 t/ha which is very low compared to major groundnut producing countries. Average yields range from 2.1 to 3.1 t/ha (Steven and Luz, 2008). Groundnut is regarded as a cash crop and is the most important oil crop.

As a result of increase in disease incidence, insect pressure and moisture stress in late season for low land pulses and cereal crops, respectively, framers are shifting their land to groundnut cultivation.

In spite of its importance as a food and cash crop, groundnut yield is low because of prolonged dry spell as well as low soil fertility conditions in the growing areas. Therefore, the major objective of the study is to identify agronomic management practices that improve groundnut production and productivity.

MATERIALS AND METHODS

Description of the study area

The study was conducted during the 2011 cropping season at Abergelle District Wereda Tabia Lemlem and Hadinet in the Central administrative Zone of Tigray, Northern Ethiopia on sandy soil. Abergelle is 120 km from Mekelle with an altitude of 1500 masl, 13°14'06"N latittude and 38°58'50" E longitude. Agro-ecologically, it is characterized as a hot warm sub-moist low land (SMl-4b). The mean annual rainfall and temperature range of the district Wereda is 350 to 700 mm and 24 to 41°C, respectively (Legesse, 1999). The mean maximum and minimum temperature of the Wereda during the 2011 growing season was 36.4 and 19.5°C, respectively. The total rainfall in Hadinet and Lemlem experimental sites during the 2011 growing season was 277 and 314 mm, respectively.

Treatments and experimental design

Groundnut cultivar Sedi, which is popular and widely used in the study area, was used in the experiment. The experimental plot was arranged in a Randomized Complete Block Design (RCBD) with three replications. Different farmers field were considered as a replication. The total plot size used was 3 m × 3 m with60 cm between rows and 20 cm between plants. The net harvestable area was 1.8 m × 3 m leaving one outer-most row as border.

Diammonium phosphate, DAP (100 kg/ha), as a source of phosphorous was applied at planting, application of gypsum 672 kg/ha was performed at flowering stage; while tied ridge and application of supplementary irrigation were done at early flowering stage and at the end of the rainy season. The tied ridge was 20 × 30 cm deep in the soil (Table 1).

Crop water requirement and irrigation scheduling

Meteorological data (maximum and minimum temperature, relative humidity, sunshine hours, rainfall and wind speed) were collected from the National Meteorology Agency, Mekelle branch. Crop water requirement was determined using modified FAO Penman Menteith method (Allen et al., 1998). Reference evapotranspiration (ET_0) was calculated based on the climatic data using CWAT software. While the other parameters were calculated as:

Crop water requirement (Etc) = $Et_o \times K_c$ (crop coefficient at each growth stage of the crop)
Gross irrigation (GI) = Net irrigation (NI)/Application efficiency (Ea), Ea was taken as 85%

NI = Etc – Pe (Pe = effective rainfall), but since there was no rainfall at supplementary irrigation time.

NI = Etc

Irrigation commenced in late September for both locations. Accordingly, supplementary irrigation water was applied for the specific treatments/plots every five days.a.

Phenological data

Data on days to 50% emergence, 50% flowering, 50% pod setting and 90% physiological maturity were recorded when the plants per plot have reached their respective phenological stages.

Yield and yield components

Yield components including number of pods/plant and number of seeds/pod were determined from measurements of five randomly selected plants per net plot area. Pods were shelled and shelling percentage was computed. Harvest index was also calculated. Dry pod and seed yield per plot area were recorded and converted to yield per hectare. Hundred seed weight was also measured.

Soil sample collection and analyses

Composite soil samples were prepared and the samples were oven dried at 105°C for 24 h and ground to pass through a 2-mm sieve for physical and chemical analyses. Soil samples were analyzed in a soil laboratory for relevant soil parameters [bulk density, permanent wilting point (PWP), field capacity (FC), organic matter, pH, nitrogen, phosphorus, potassium, exchangeable Ca, Mg and soil texture.

In the laboratory, exchangeable bases (potassium, calcium and magnesium) were determined by ammonium acetate method. Besides, soil texture was determined by Hydrometer method. Total nitrogen was determined using the Kjeldahl method as described by Jackson (1967). Available phosphorus was determined using

Table 1. List of treatments and treatments combinations.

Number	Treatment	Number	Treatment
1	Control (C)	9	SI + TD
2	Gypsum (GP)	10	SI + F
3	Supplementary Irrigation (SI)	11	TD + F
4	Tied ridge (TD)	12	GP + SI + TD
5	Fertilizer (F= DAP)	13	GP + SI + F
6	GP + SI	14	GP + TD + F
7	GP + TD	15	SI + TD + F
8	GP + F	16	SI + TD + F + GP

spectrophotometer following the Olson extraction method (Olsen and Dean, 1965). pH was measured from the composite soil sample in a suspension of 1:2.5 soil to water ratio as described by Jackson (1958). Organic matter was determined by the Walkley and Black wet oxidation organic carbon method as described by Jackson (1967).

Statistical analyses

Analysis of variance (ANOVA) was carried out on yield and yield components of groundnut using Genstat software, 13th edition. Treatment means showing significance at 5% level were compared using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Soil characteristics

Results from the soil analyses indicated the proportion of sand, silt and clay was 94, 1 and 5%, respectively, indicating that the textural class of the experimental sites are sandy. Besides the pH values of soils from Hadinet and lemlem were 7.04 and 7.06, respectively, indicating sites are ideal for groundnut production. The organic carbon content (%), available phosphate (mg/kg) and total nitrogen (%) of Hadinet and Lemlem experimental sites were 0.26, 6.41, 0.08 and 0.14, 3.51, 0.05, respectively.

Crop phenology

The effect of the different agronomic management practices tested is presented in Table 2. The analysis of variances indicated that no significant differences ($P<0.05$) were observed among the different management practices in days to 50% flowering. However, the duration to full maturity days was significantly longer in Lemlem which could be due to better rainfall amount and distribution. Early maturity (97 days), which might be forced maturity resulting from stress resulted in lower yield in the control. On the other hand, the longest maturity days of 109 was recorded in supplementary irrigation + tied ridge + fertilizer (DAP) and gypsum management options implemented (Table 2).

Meanwhile, significant difference ($p<0.05$) was observed in plant height at Hadinet experimental site. Application of DAP fertilizer, tied ridge, supplementary irrigation and gypsum showed a significant effect ($p<5\%$) over the control. No consistent result was observed from the different combinations, and hence no significant results were observed among most of the treatment combinations (Table 2). Overall combined applications showed a significant effect on plant height over the control. A maximum height of 25.13 cm was obtained from combined treatment of supplementary irrigation and tied ridging while the shortest height of 8.77 cm was observed for the control at Hadinet (Table 2).

Number of pods per plant

The analysis on number of pods per plant indicated that there was a significant ($p<0.001$) difference among the evaluated management options at both locations. The highest values of 23.53 and 21.8 pods/plant were recorded in supplementary irrigation + tied ridge + fertilizer (DAP) and gypsum + supplementary irrigation management practices in Hadinet and Lemlem, respectively (Table 4). The lowest values of 5.97 and 8.33 pods/plant were recorded in the control at Hadinet and Lemlem, respectively. Application of supplementary irrigation+ tied ridge+ fertilizer (DAP) + gypsum differed significantly on number of pods per plant over the control when these treatments were practiced alone (Table 3). From all combination practices, application of supplementary irrigation+ tied ridge+ fertilizer and supplementary irrigation+ tied ridge+ gypsum showed a significant difference on the number of pods per plant ($p<5\%$) over the control as well as other combinations (Table 3). From this result, it can be suggested that application of supplementary irrigation and tied ridge together with fertilizer application showed better number of pods per plant. Hence ridging and supplementary irrigation improves the moisture status of the soil and as a result buffers against extreme moisture and reduces stress (heat and drought), which results in normal flowering, pod development as well as kernel

Table 2. Mean values of days to flowering, maturity and height of groundnut at Hadinet and Lemlem.

Treatment	Location					
	Hadinet			Lemlem		
	DTF	DTM	PH (cm)	DTF	DTM	Ht (cm)
C	39.33	107.00	8.77^{a}	39.67	97.67^{a}	14.40
F	41.33	108.00	17.47^{b}	41.33	105.00^{bc}	18.53
GP	39.33	108.67	19.87^{bcd}	39.00	102.67^{ab}	20.00
GP + F	44.00	111.00	18.20^{bc}	41.33	105.33^{bc}	18.87
GP + SI + TD	39.33	109.00	21.73^{bcde}	40.67	107.67^{bc}	18.93
GP + SI	39.33	112.67	22.43^{bc}	40.67	107.33^{bc}	19.67
GP + SI + F	41.33	110.00	23.77^{de}	40.33	107.67^{bc}	17.93
GP + TD	40.33	110.67	18.60^{bc}	39.00	104.33^{bc}	20.07
GP + TD + F	40.33	110.00	20.73^{bcde}	40.00	108.00^{bc}	18.53
SI	39.33	106.00	20.53^{bcde}	39.00	108.33^{c}	19.73
SI + F	41.33	111.00	21.73^{bcde}	43.00	108.00^{bc}	17.60
SI + TD	40.33	110.00	25.13^{e}	40.67	107.33^{bc}	19.53
SI + TD + F	40.33	110.67	23.87^{de}	41.33	109.33^{c}	17.93
SI + TD + F + GP	41.33	112.00	24.60^{e}	40.33	106.67^{bc}	20.07
TD	39.33	107.00	17.83^{bc}	39.00	104.00^{bc}	20.53
TD + F	40.33	110.00	19.13^{bc}	42.00	104.67^{bc}	21.53
DMRT $_{a}$ 0.5	ns	ns	4.621	ns	5.560	ns
CV (%)	5.32	2.81	13.7	6.63	4.6	11.4

C=Control, F=Fertilizer (DAP), GP=Gypsum, SI=Supplementary Irrigation, TD=Tied ridge, DTF=days to flower, DTM=days to maturity, PH=plant height. Means having the common letter are not significantly different at the 5% level of significance.

Table 3. Mean pods/plant, seeds/pod and 100-seed of groundnut at Hadinet and Lemlem testing site.

Treatment	Location					
	Hadinet			Lemlem		
	Pods/plant (No.)	Seeds/pod (No.)	100-seed weight (g)	Pods/plant (No.)	Seeds/pod (No.)	100 seed weight (g)
C	5.97^{a}	2.2	34.67^{a}	8.33^{a}	2.2	34.07^{a}
F	15.00^{bcd}	2.7	46.50^{bc}	18.47bcde	2.5	39.30^{b}
GP	14.73^{bcd}	2.7	46.10^{b}	17.93^{bcde}	2.7	41.00^{bcd}
GP + F	12.07^{b}	2.4	46.47^{bc}	16.53^{b}	2.8	42.30^{bcdef}
GP + SI + TD	20.00^{efg}	2.6	51.93^{d}	20.40^{def}	2.6	43.30^{def}
GP + SI	18.40^{def}	2.5	50.13^{cd}	19.60^{cdef}	2.8	44.43^{ef}
GP + SI + F	16.27^{bcdef}	2.3	48.30^{bcd}	17.40^{bcd}	2.4	42.20^{bcdef}
GP + TD	11.93^{b}	2.5	46.80^{bc}	16.00^{b}	2.7	43.83^{def}
GP + TD + F	13.33^{bc}	2.7	45.80^{b}	16.53^{b}	2.7	41.57^{bcde}
SI	13.87^{bc}	2.8	50.93^{d}	16.87^{bc}	2.4	44.20^{ef}
SI + F	16.07^{bcde}	2.7	46.50^{bc}	16.00^{b}	2.6	40.03^{bc}
SI + TD	17.57^{cdef}	2.4	49.10^{bcd}	20.67^{ef}	2.5	45.07^{f}
SI + TD + F	23.53^{g}	2.5	51.13^{d}	16.00^{b}	2.5	41.00^{bcd}
SI + TD + F + GP	20.53^{fg}	2.4	49.73^{bcd}	21.80^{f}	2.7	43.00^{cdef}
TD	13.27^{bc}	2.4	48.47^{bcd}	18.33^{bcde}	2.7	44.80^{f}
TD + F	13.07^{b}	2.5	48.70^{bcd}	19.87^{cdef}	2.5	43.73^{def}
DMRT$_{a}$ 0.5	4.377	ns	4.033	3.066	ns	3.196
CV %	17.1	8.2	5.1	10.5	8.2	4.6

Means having the common letter are not significantly different at the 5% level of significance.

development. In line with this it has been reported that pod and kernel development are progressively inhabited

Table 4. Mean yield of dry pod, kernel yield and shelling percentage of groundnut at Hadinet and Lemlem testing site.

Treatment	Location					
	Hadinet			Lemlem		
	Dry pod weight (kg/ha)	Kernel yield (kg/ha)	Shelling (%)	Dry pod weight (kg/ha)	Seed yield (kg/ha)	Shelling (%)
C	772[a]	290[a]	0.378	1142[a]	485[a]	0.4268
F	1481[cdeb]	543[abc]	0.374	1420[abc]	642[abc]	0.4553
GP	1327[bcd]	671[bcdef]	0.478	1759[bcde]	845[bcd]	0.4799
GP + F	957[ab]	612[abcd]	0.768	1420[abc]	641[abc]	0.4460
GP + SI +TD	1543[cdef]	950[ef]	0.628	1728[bcde]	876[cd]	0.5030
GP + SI	1728[def]	911[def]	0.491	1790[cde]	959[d]	0.5371
GP + SI + F	1512[cde]	694[bcdef]	0.459	1512[abcd]	755[abcd]	0.4996
GP + TD	1296[bc]	683[bcdef]	0.517	1759[bcde]	880[cd]	0.4877
GP + TD + F	1420[cde]	536[ab]	0.376	1327[ab]	585[ab]	0.4375
SI	1358[bcde]	748[bcdef]	0.569	2037[e]	941[d]	0.4651
SI + F	1636[cdef]	751[bcdef]	0.450	1574[abcd]	708[abcd]	0.4520
SI + TD	1728[def]	659[bcdef]	0.381	1759[de]	848[d]	0.4752
SI + TD + F	1941[f]	980[f]	0.490	1423[abc]	640[abc]	0.4445
SI + TD + F + GP	1543[ef]	863[cdef]	0.486	1698[bcde]	854[bcd]	0.5017
TD	1420[cde]	654[bcde]	0.452	1790[cde]	889[cd]	0.4924
TD + F	1265[bc]	601[abcd]	0.476	1605[bcde]	824[bcd]	0.5128
$DMRT_a$ 0.5	402.8	325.2	ns	441.6	284.6	ns
CV (%)	16.7	28	38.9	16.4	21.9	12.4

Means having the common letter are not significantly different at the 5% level of significance.

by drought stress due to insufficient plant turgor and lack of assimilates. Pod and kernel development may also be delayed by lack of soil water in pod zone (Boote and Ketring, 1991; Stirling and Black, 1991). It was also reported that number of pods per plant can be low due to increasing soil resistance (dryness of the soil as a result of moisture stress which resulted in difficulty of pegs to penetrate into soil for pod formation) caused by prolonged drought (Sharma and Sivakumar, 1991).

Number of seeds per pod

Analysis of variance indicated that the different integrated soil moisture conservation and soil fertility amendment agronomic management practices did not affect number of seeds per pod at Hadinet and Lemlem sites (Table 3). The main reason for the non-significance among the different management options might be due to the genetic potential of the variety used during the study. In line with this, it has been reported that the number of seeds per pod is under a genetic control even though environment and internal competitions might have an influence (Ashley, 1984).

Hundred seeds weight

Significant difference ($p < 0.001$) was observed among treatments in terms of 100-seed weight at both locations (Table 3). The highest 100-seed weight (51.93 and 45.07 g) was recorded in gypsum + supplementary irrigation + tied ridge treatment combinations at Hadinet and supplementary irrigation + tied ridge treatment combinations at Lemlem sites, respectively (Table 3). In both sites, the lowest 100-seed weight was observed in the control. In both locations, the integration of both moisture conservation practices with soil fertility amendment practices showed a better improvement on 100-seed weight of groundnut than the single application of management practices. But no superior advantage was observed between the moisture conservation practices (tied ridging and supplementary application) at both locations (Table 3). These values of 100-seed weight agreed with findings of Mukhtar (2011) who reported that the values of 100-seed weight of groundnut ranged between 45.92 and 50.41 g in which different groundnut varieties were evaluated under different population density and basin sizes.

Dry pod yield and kernel yield

Analysis of variance indicated that a significantly different dry-pod and kernel yield ($p<0.01$ at Hadinet; $p=0.03$ at Lemlem) was recorded among the treatments (Table 4). The highest dry-pod yield and kernel yield of 1941 and 980 kg/ha, respectively were found in treatment

Table 5. Mean yield of dry biomass and harvest index of groundnut in Hadinet and Lemlem experimental site.

Treatment	Location			
	Hadinet		Lemlem	
	Dry biomass weight (kg/ha)	HI (%)	Dry biomass weight (kg/ha)	HI (%)
C	2043[a]	0.145	2348[a]	0.2058
F	3136[bc]	0.182	3451[def]	0.1867
GP	3068[bc]	0.207	3177[bcde]	0.2665
GP + F	2272[ab]	0.317	3300[cdef]	0.1931
GP + SI + TD	3718[cd]	0.253	3277[cdef]	0.2662
GP + SI	3734[cd]	0.229	3664[f]	0.2615
GP + SI + F	3264[cd]	0.210	2941[bc]	0.2568
GP + TD	3098[bc]	0.218	2790[b]	0.3295
GP + TD + F	2881[abc]	0.184	2842[b]	0.2063
SI	3216[bcd]	0.230	3085[bcd]	0.3096
SI + F	3389[cd]	0.218	2853[b]	0.2469
SI + TD	4092[d]	0.165	3161[bcde]	0.2885
SI + TD + F	4118[d]	0.238	2327[a]	0.2717
SI + TD + F + GP	4129[d]	0.212	3540[ef]	0.2403
TD	2973[abc]	0.216	3138[bcd]	0.2827
TD + F	3116[bc]	0.191	3303[cdef]	0.2504
$DMRT_a$ 0.5	944.7	ns	388.3	ns
CV (%)	17.3	35	7.6	24.8

Means having the common letter are not significantly different at the 5% level of significance.

combination of supplementary irrigation + tied ridge + fertilizer (DAP) at Hadinet, while the highest pod and seed yield (2037 and 941 kg/ha, respectively) was found at Lemlem in the treatments supplementary irrigation and application of gypsum + supplementary irrigation, respectively (Table 4). No significant difference in yield was observed between the control and the DAP treated plots at Lemlem. While at Hadinet, application of DAP showed significant effect over the control (Table 4). Application of gypsum as source of calcium showed a significant effect in pod yield in both locations alone and in combination with other management options.

In line with this, the application of gypsum as a source of calcium is well documented and is widely used as a source of Ca for groundnut production worldwide, depending on the fertility status of the soil (Mupangwa and Tagwira, 2005).

The results showed that the combined effect of gypsum, fertilizer with tied ridging and supplementary irrigation practices are the best options for enhancing production and productivity of groundnut at both experimental locations. The effect of soil fertility and moisture retention enhancement on groundnut is well studied. Accordingly, the result of this finding agrees with the work of Yebio et al. (1987) who reported that pod yield under irrigation ranged from 3.5 to 6.5 t/ha. According to De et al. (2005) ridge planting method not only maintained slightly higher soil moisture (8.4%) compared to the flat planting method (7.3%), but also produced higher kernel yield (0.57 t/ha) than flat planting (0.42 t/ha). In similar manner, studies had been conducted on the role of tied ridge in moisture conservation, thereby, enhancing yield of crops. Tied ridges have been found to be efficient in storing rain water, which results in substantial grain yield increase in some major dryland crops like sorghum, maize, wheat and mung beans in Ethiopia. The average grain yield increased from 50 to 100% in tied ridge and traditional practice, respectively (Georgis and Takelle, 2000) though this increase varies according to soil type, slope, rainfall and the crop grown.

Dry biomass yield

Statistical analysis of data revealed that the application of DAP, gypsum and supplementary irrigation alone and in double combination of each other showed a significant effect (p<5%) over the control (Table 5). Across all the combination treatments, no consistent trend was observed. Application of gypsum + Fertilizer application, gypsum + tied ridge + fertilizer (DAP) and tied ridge practices alone did not show significant effects over the control (Table 5). The highest and lowest dry biomass yield of 4129 and 2043 kg/ha, respectively were recorded from plots that received supplementary irrigation + tied ridge + fertilizer (DAP) + gypsum and the control at Hadinet, respectively. At Lemlem, the highest dry biomass yield of 3664 kg/ha was recorded in management options where gypsum + supplementary irrigation were implemented. Meanwhile, both the soil fertility amendments (DAP and gypsum) and moisture conservation practices (supplementary irrigation and tied ridges) did not statistically differ in dry biomass yield when tested without integration with each other (Table 5).

Harvest index

No significant difference was observed in harvest index among the treatments at both sites (Table 5). Harvest index explains the relationship between grain yield (economic yield) and total biological yield and reflects the state of dry matter partitioning into grain yields.

CONCLUSION AND RECOMMENDATIONS

From the soil fertility amendment management practices, at Hadinet gypsum application considerably increased dry pod and kernel yield of groundnut by 72 and 131% over the control, respectively. While at Lemlem experimental site 54 and 74% of dry pod and kernel yield increment over the control were recorded, respectively.

Application of supplementary irrigation together with tied ridging and fertilizer significantly improved dry pod yield and kernel yield of groundnut at Hadinet experimental site.

The experiment showed that in areas where water for supplementary irrigation is not available, application of tied ridge becomes an alternative option for improving production and productivity of groundnut.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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