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Improved crop-management techniques for better groundnut (*Arachis hypogaea* L.) production in Western Kenya

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ABSTRACT

Poor agronomic and husbandry practices are largely responsible for the low yields of groundnuts in Western Kenya. This study was undertaken to develop agronomic practices for increasing groundnut yields by small-hold farmers of Busia, Teso and Siaya districts of Western Kenya. Four experiments-to test sowing time and weed control, to develop a suitable seedbed for groundnut production, to screen available germplasm for high yielding lines, and to test various fertilizer types for use in groundnut production, were set up. These experiments were laid in farmers' fields. It was observed that an early and finely prepared seedbed increased pod yields significantly ($p \leq 0.05$) above the traditional practice. Such a fine seedbed slowed weed emergence and buildup thereby increasing the weed-free duration for the crop. There were no significant benefits of two weeding operations over the traditional single weeding largely as a result of the seedbed used. Consequently, by investing on a good seedbed, a farmer could save on weeding expenses. Sowing groundnut in the first week of the rains led to a significantly ($p \leq 0.05$) higher yield over subsequent dates. Groundnuts responded to fertilizer types differently. (Diammonium phosphate (DAP) and NPK mixed fertilizer applications increased dry pod yields by 22-50% ha^{-1} over the control. The organic fertilizers, compost and *Rhizobium* inoculant, were not effective in this study. At the rate of 10 t /ha, compost increased pod yield by only 2% over the control. Inoculant application to groundnuts did not lead to significant increases in pod yields. Since no root examination was made for nodules it is not ascertained if the operational factors were extraneous to the isolate or not. Among the entries tested, ICGVSM 90904 and 93535 from ICRISAT, Malawi consistently out-performed the traditional variety, Red Valencia, across locations and over seasons. It is proposed that the seed of the two lines be multiplied and distributed to a nucleus of farmers for further evaluation and multiplication. Due to difficulties in acquiring larger volumes of compost in the farms and the high cost of inorganic fertilizers, a study on combined application of organic and inorganic fertilizers to come up with affordable but effective rates is also proposed.

Key words: Arachis hypogaea, farmers, improved crop management, technologies.

INTRODUCTION

In Kenya, groundnut (*Arachis hypogaea* L.) is grown mainly in the Western region (Okiror *et al.*1997). Its annual production and area cultivated are estimated at 12,000 M tonnes and 18,000 ha respectively, both of which are lowest in East Africa region (FAO 1998). This is attributed to several factors. Its consumption levels as both a food and cash crop have fluctuated perhaps due to insignificant importance given to it by many small-scale farmers. As food, its consumption has been rather confined to specific human cultures. Nonetheless, the consumption of groundnuts has steadily increased in the entire Kenya nation and the cash aspect is overtaking the local consumption aspect. This is based on the volumes informally brought in from both Uganda and Tanzania to supplement local supplies. Use of poor quality seed, non-use of fertilizers, lack of disease/pest control, and overall poor crop husbandry including very low populations (under maize-groundnut intercropping) are other factors cited for the low yields (Oggema *et al.* 1988; Okiror *et al.* 1997).

Time of sowing is critical in groundnut production particularly under rainfed conditions. Each week's delay after the recommended sowing time has been found to decrease yield by between 20 and 30%, but in other crops, e.g. Sesame (*Sesamum indicum* L.) sowing at the onset of rains gave a significantly higher yield than any subsequent sowing (Jain *et al.*1988). Besides better yields, early sowing is also an applied strategy in wilt and rosette management of groundnut (Naidu *et al.*1999). Adequate and timely land preparation is an essential agronomic practice that enables timely planting and provides a deep soil and well-made seedbed. Such a seedbed serves to reduce the number of cultivations between planting and harvesting and gives the crop a head start over weeds (Goldston 1967). Furthermore, germination and plant stands are usually rapid and uniform (Reddy 1988). Most farmers make the seedbed by hand-hoes and only a few of them make seedbeds by animal-drawn ploughs. In both instances, the seedbeds tend to be cloddy and uneven. Seeds planted on these beds are therefore sown at variable depths with moisture variations and so emerge unevenly. The hand hoe alone is a poor tool for seedbed preparation and is inefficient for deep tillage.

It is a fact that weed management determines the production efficiency of a farm (Reddy 1985). From studies of local practices of groundnut cultivation, it is acknowledged that poor weeding is a limiting factor (Okiror *et al.*1997). Farmers carry out a single weed control operation using the hand hoe, usually at flowering. Groundnut is very sensitive to weed competition in the early stages of growth; weed control especially in the first 45 days after sowing is very critical in groundnut production (Goldston 1967; Upadyay 1985). A groundnut crop that was not weeded at all yielded less than 30% of weedfree one (Rao *et al.*1989), while a weed-free environment increased pod yield four-fold (Goldston 1967).

Another major limiting factor is lack of improved groundnut varieties. Thus there is an over-dependence on a single variety, the Red Valencia, in Western Kenya. Moreover, this variety is no longer genetically pure. It is now a mixture of several homozygous lines (personal observation by Okiror). This contamination has largely arisen due to the predominant use of market seed and/or farmer-to-farmer seed exchange and absence of groundnut seed-producing and distribution agencies. New strategies are needed, therefore, to clean up this variety and/or generate new and superior varieties.

Nutrient depletion in soils of Western Kenya is widespread and acknowledged by both farmers and researchers (Okalebo *et al.*1999). This is mainly due to continuous cultivation of the land with little or no nutrient replenishment. Organic or inorganic fertilizers, are rarely applied to groundnut despite benefits evident in a maize- groundnut rotation or intercropping where maize was fertilized. Liming soils for groundnut production enhances uptake of N and P elements by the groundnut crop leading to good growth and high yields. Although groundnut can supply most of its nitrogen needs through symbiotic N_2 fixation, a starter dose of nitrogen fertilizer is necessary. Various forms of organic manure are readily available in most homesteads though in limited quantities. Moreover, raw material and its degree of decomposition, time and method of placement and quantities applied affect its effectiveness. Application of 10 t/ha was reported to boost yields of groundnut tremendously (Chikowo *et al*.1999). This study was therefore undertaken to develop strategies for increased productivity of groundnuts in Western Kenya.

MATERIALS AND METHODS

Sites

Studies were set up at six on-farm sites, two each from Busia, Siaya and Teso districts. The Busia farms were located within 0^0 25'N and 33^0 54'E, 1375 masl and received a bimodal rainfall pattern with annual precipitation varying between 1270 to 1790 mm. The soils are characteristically well drained, deep brownish sandy with moderate water-holding capacity. Those for Siaya lie within 0^0 18'N, 34^0 33'E, 1400 masl. The soils are red volcanic sandy loams. Annual precipitation is about 1500 mm distributed over long (March to April) and short (August to October) rain seasons. In Teso, the farms were sited within 0^0 34'N, 34^0 07'E, 1300 masl. The soils are well drained, shallow to very deep friable sandy clay. This area too has a bimodal rainfall pattern with amounts averaging 1550 mm annually. All the farms used as study sites are either in lower midland 1 or 2 agro-ecological zones. The three districts were selected for these studies because they are the main groundnut producing districts of the country. The criterion for farm selection was an active cultivation of groundnuts in the area and willingness of farmers to provide land and collaborate in studies. Four experiments were set up. They were designed by the researchers but managed by the farmers, and were carried out for four seasons, beginning short rains 1998 to long rains 2000. In all seasons and for all sites, all the four experiments were set up.

Studies

Sowing time and weed control

The time of planting and weed control were studied simultaneously. Three time periods of planting were used: T_1 = a week after onset of rains; T_2 = two weeks after onset of rains, and T_3 = three weeks after onset of rains. Also two methods of weed control were used: W_1 = a single hand weeding in the 7^{th} week, and W_2 = two hand weeding operations, 4^{th} and 7^{th} weeks. The levels of the two factors were constituted into six treatments (T_1W_1, T_1W_2, T_2W_1, T_2W_2, T_3W_1, and T_3W_2). Since W_1 represented the standard weed management practice and T_3 the common timing of planting, treatment combination T_3W_1 represented the control. The treatments were arranged in a factorial combination. The test variety was Red Valencia and the seedbed type used was the farmer's type.

Seedbed preparation

Two seedbed preparations were investigated: the farmers' practice (FT) and recommended type (RT). The FT was done in the way farmers usually make their seedbed preparations, namely, a single tillage by hand-hoe, followed by minimal removal of crop residues and other vegetation and breaking of clods. The hoe can dig deep up to about 4 cm. The RT, on the other hand, was an improvement over FT. The field was first ploughed during the dry season mostly to loosen the soil, break soil clods and bury weed seed. A second ploughing followed as rains commenced. Using hand-hoes large soil clods were beaten to a smooth tilth and prepared into a raised, flat bed devoid of vegetation and trash on which seed was eventually sown. Planting was done within week one from the onset of rains and weeding done twice, in the fourth and seventh weeks using the hand-hoe. The test variety was also Red Valencia.

Germplasm-base enhancement and screening

Several improved lines originally from the SADC/ICRISAT groundnut program, Malawi, were obtained from Western Agricultural Research Centre (WARC), Kakamega. These were ICGVM 88710 and 89947, ICGVSM 90100, 90904 and 93535, ICG 9991, ICG MS-5, GG 7 and JL 24. Together with two local landraces White Valencia (W.V.) and Homa Bay (H.B.), they were evaluated for adaptation, agronomic traits and yield alongside Red Valencia, the common variety in the region. Due to limited quantity of seed, screening was first done in two-row, 4 m long plots. Subsequently, the standard plot size (as reported below) was used. Planting was done within the first week of onset of rains on improved type seedbed but without any fertilizer. However the plots were weeded twice, in the fourth and seventh weeks.

Soil-fertility enhancement

Four kinds of fertilizer were tested for their potential in improving groundnut yield. These were rhizobium inoculant (R.I.), farmyard manure or compost (FYM), Diammonium phosphate (DAP, 18-46-0) and NPK (20-20-0) compound fertilizer. The inoculant was a general legume strain of *Rhizobium* provided by the Microbiology Research Center (MIRCEN) Project of the University of Nairobi. It was mixed at the ratio of 1:20 (w/w) with groundnut in a little water to make a slurry and ensure sufficient seed coating. The seed-inoculant mixture was covered in a moist sack to prevent drying of coated seed. The compost was farm-made and applied at the rate of 10 t /ha. But the inorganic fertilizers were applied in quantities to give 15 kg N and 17 kg P / ha. They were applied into the planting holes while the manure was applied uniformly as a band into 2-cm deep furrows, and covered with soil before placement of seed. The control was the non-use of any fertilizer, and the experimental variety was Red Valencia. The study was also set up within the first week of the rains and was weeded twice, in 4^{th} and 7^{th} weeks.

Experimental Design

All field trials were laid out as a randomized complete block design (RCBD) with 3 replicates. Plots were 5 m x 1.8 m accommodating 5 rows spaced 0.45 cm apart. Seeds were sown 10 cm apart along the rows for all studies. All plantings were done within the first week of the onset of rains in all seasons. In case of study 1, a further two plantings were made in the second and third weeks after the onset of the rains. Planting was done in March for long rains season and September in the short rains season.

Data collection and analysis

Ten plants per plot were randomly tagged from the inner three rows for data collection. The parameters studied were emergence counts, plant height and number of plant branches, seed counts and pod yield. Harvesting was done when the plants reached physiological maturity, pods sun-dried as traditionally done by farmers and weighed. They were shelled and seed thereof further sun-dried for two days before weighing. Combined analyses of variance (ANOVA) across districts and farms were conducted separately on data from the two seasons using the general linear model (GLM). The computer software program SAS (SAS, 1996) was used for data analysis and the least significant difference ($LSD_{0.05}$) test was then employed to separate significant treatment means.

RESULTS

The long rains seasons were characterized by early onset of rains which remained average throughout the growing season while the short rains were a little delayed (a week to two weeks), were heavy at onset but gradually decreased. In all seasons no noticeable threat to crop growth as a result of drought was experienced.

Optimum sowing time and weed control

Sowing of groundnut within the first week of onset of rains (T_1), gave significantly higher yields than delayed sowing and this effect was observed in both long and short rains seasons of 1998, 1999 and 2000 (Table 1). A yield of 1940 kg ha^{-1} of dry pod was obtained by sowing at the onset of rains (T_1) against 1,100 and 800 kg ha^{-1} in subsequent sowing dates, T_2 (two weeks) and T_3 (three weeks) during the long rains season. This trend was repeated during the short rains season where more than 2,100 kg ha^{-1} pods were harvested compared to 1,800 and 1,400 kg ha^{-1} in respective planting dates. Groundnut is traditionally cultivated during the short rains and less so during the long rains in Western Kenya. Thus the large seasonal differences in yields are not unexpected. Sowing dates also significantly ($p < 0.05$) affected seed weight/plant in both seasons, plant height in long rains, and pod and branch numbers in short rains. Although sowing dates affected the other traits, the differences were insignificant. The various weed management strategies studied did not cause significant changes in the measured traits. In fact only the number of primary branches/plant was increased by two weeding operations (W_2). Two weeding operations also marginally increased pod yields/ha by 89 kg ha^{-1} in the long rains and by 168 kg ha^{-1} in the short rains. There were no significant interactive effects between time of sowing and weed control for all traits in both seasons. However, considering pod yield, the treatment combinations T_1W_1 (sowing in first week plus a single weeding) and T_1W_2 (sowing in first week plus two weeding operations) consistently gave the highest yields while T_3W_1 (sowing three weeks later plus one weeding) had the lowest yields.

Table 1. Influence of planting time and weed management on the performance of groundnut (Red Valencia) in the long and short rains seasons of 1998, 1999 and 2000 in Western Kenya.

Parameter		Emergence (%)	Plant ht (cm)	Branches/ plant	Weight.seed /plant (g)	Number pods/plant	Pod yield Kg/ha
				Long rains			
Time of planting							
T1		84.0	20.5	4.5	4.7	30.0	1937
T2		77.0	17.8	4.5	2.5	24.0	1134
T3		79.0	17.1	4.2	2.2	20.0	826
$LSD_{0.05}$		NS	2.7	NS	1.5	NS	675
Weed control							
W1		80.0	18.2	4.2	2.8	25.0	1254
W2		80.0	18.7	4.5	3.4	25.0	1343
$LSD_{0.05}$		NS	NS	0.3	NS	NS	NS
Interactions							
T1	W1	83.0	20.1	4.4	5.6	28.7	2141
T1	W2	84.0	20.8	4.5	3.9	31.3	1733
T2	W1	79.0	18.0	4.4	2.4	26.7	1104
T2	W2	75.0	17.6	4.6	2.6	22.1	1163
T3	W1	77.0	16.4	4.0	2.2	18.7	785
T3	W2	81.0	17.7	4.4	2.1	21.3	867
$LSD_{0.05}$		NS	NS	NS	NS	NS	NS
				Short rains			
Time of planting							
T1		76.0	23.1	5.2	6.0	9.2	2122
T2		83.0	25.1	4.8	4.6	8.0	1830
T3		81.0	20.9	4.7	3.8	6.7	1396
$LSD_{0.05}$		NS	NS	0.3	1.1	1.0	402
Weed control							
W1		89.0	23.6	4.7	4.6	7.9	1699
W2		80.0	22.4	5.0	5.0	7.9	1867
$LSD_{0.05}$		NS	NS	0.3	NS	NS	NS
Interactions							
T1	W1	77.0	22.8	5.0	6.5	9.6	2222
T1	W2	75.0	23.4	5.4	5.4	8.9	2022
T2	W1	81.0	26.7	4.7	4.5	7.8	1771
T2	W2	84.0	23.4	4.9	4.6	8.1	1889
T3	W1	81.0	21.3	4.6	3.9	6.4	1355
T3	W2	80.0	20.5	4.7	3.7	6.9	1437
$LSD_{0.05}$		NS	NS	NS	NS	NS	NS

Emergence % = number seedlings germinated relative to seed sown, height = the length of main branch, branches/plant = primary branches only, pods/plant = filled pods only, Yield/ha = weight of dry pods/ha.
T_1 = a week after onset of rains, T_2 = two weeks after onset of rains, and T_3 = three weeks after onset of rains; W_1 = a single hand weeding in the 7th week, and W_2 = two hand weeding operations, 4th and 7th weeks.

Seedbed preparation and its quality

The improved seedbed (RT) led to significantly higher pod yields ($p < 0.05$) than the farmers' practice (FT) (Table 2). Groundnuts sown in the improved seedbed yielded 2,400 and 2,300 kg ha^{-1} of pods compared to 1,700 and 1,500 kg ha^{-1} in FT for the two seasons respectively. This 47–52% pod yield increase is attributed to both the additional labour on the RT seedbed preparation and improved physical condition of the soil. Significant increases ($p < 0.05$) were also observed in seed weight/plant and number of pods/plant as a result of improved seedbed. In both instances the improved seedbed was superior to the farmer's seedbed. In the rest of the traits, seedbed effects were non-significant and contradictory in a few cases. For instance, emergence was consistently lower in the RT than in the FT seedbeds. Plant height and number of primary branches were identical in the two seedbed types.

Germplasm enhancement and variety development

Of the nine elite lines tested, results are presented for only three (Table 3). Besides limited initial seed acquisition, only a few plants emerged in the other lines and gave few pods. Thus their results are excluded.

Table 2. Effect of seedbed preparation technique and its quality on the performance of groundnut (Red Valencia) during long and short rains seasons of 1998, 1999 and 2000 in Western Kenya.

Seedbed type	Emergence (%)	Height (cm)	# branches per plant	Seed weight /plant (g)	No. pods /plant	Pod yield Kg ha
			Long rains			
FT	79.0	24.7	4.0	4.4	8.0	1653
RT	77.0	25.5	5.0	5.3	12.0	2429
$LSD_{0.05}$	NS	NS	NS	0.3	1.9	618
			Short rains			
FT	82.0	19.0	5.0	4.0	7.0	1538
RT	75.0	19.0	5.0	6.1	8.0	2342
$LSD_{0.05}$	NS	NS	NS	0.5	0.9	670

FT = farmer's method of seedbed preparation, RT = improved method being demonstrated

Table 3. Evaluation of the performance of elite groundnut lines and local landraces against Red Valencia during the long and short rains seasons of 1998, 1999 and 2000 in Western Kenya.

Test line	Emergence (%)	Height (cm)	# branches /plant	Seed weight /plant	#pods/ plant	Pod yield Kg/ ha
			Long rains			
H.B.	76.0	18.1	5.5	4.4	7.0	1100
R.V. (control)	84.0	22.5	4.2	5.5	9.0	2541
90904	80.0	13.9	5.7	7.2	16.0	3904
W.V.	81.0	20.6	4.3	5.3	13.0	2400
JL 24	79.0	19.4	4.1	5.1	11.0	2467
93535	77.0	13.9	4.8	5.9	13.0	2911
$LSD_{0.05}$	NS	1.9	0.8	NS	3.9	944
			Short rains			
H.B.	79.0	18.7	6.5	4.2	7.0	1622
R.V.	76.0	27.8	5.1	6.0	9.0	1940
90904	80.0	18.6	6.9	8.1	13.0	3214
W.V.	83.0	20.2	5.0	5.1	10.0	1889
JL 24	85.0	19.5	5.3	6.2	10.0	2489
93535	86.0	16.4	4.8	6.8	10.0	3111
$LSD_{0.05}$	3.9	4.8	0.5	1.6	2.6	674

H.B. and W.V = landraces; R.V. = current variety; 90904, 93535 and JL 24 = ICRISAT germplasm

Large differences ($p < 0.05$) were observed between the treatments in all traits except germination and seed weight in the long rains season. Emergence rates were high (>80%) in lines 93535, JL 24 and W.V. Red Valencia had the lowest rate at 76%. The seed viability of all test lines was, therefore, good. Red Valencia, the traditional variety, was consistently the tallest entry (23 and 28 cm for long and short rains, respectively) while the elite lines ICGVSM 90904 and 93535 were the shortest (14-cm). The other entries were in between these height ranges. The elite line 90904 had the most primary branches (6 in short rains and 7 in the long rains) and pods (16 and 13 pods/plant) while RV, WV and JL 24 had 4 or 5 primary branches. The line

90904 too gave the highest seed weight (7 and 8 g/plant). Red Valencia produced the fewest pods (9/plant in both seasons) and lowest seed weight (5 and 6 g/plant). Pod yield differences were significant among the entries. The largest yields, about 3,214 (short rains) and 3,904 (long rains) kg ha^{-1} were observed in line 90904. This was about 25% higher than 93535. Homa Bay, a landrace, was consistently low yielding (1100 and 1622 kg ha^{-1} for long and short rains seasons, respectively). All ICRISAT entries gave higher yields than Red Valencia in the combined evaluation.

Effect of fertilizer on groundnut production

The application of various fertilizer types to improve soil fertility did not markedly affect groundnut performance (Table 4). Only three traits, emergence ($p < 0.05$) and pod setting ($p < 0.05$) in long rains, and plant height ($p < 0.05$) in short rains were significantly affected. The organic fertilizers, FYM and *Rhizobium* gave higher emergence rates ($p < 0.05$) compared to the inorganic fertilizers, DAP and NPK and the control. Both inorganic fertilizers drastically lowered emergence, with the biggest effect coming from DAP fertilizer.

Table 4. Effect of various soil amendments on agronomic and yield traits of groundnuts (Red Valencia) during long and short rains seasons of 1998, 1999 and 2000 in Western Kenya.

Fertilizer	Emergence (%)	Plant height (cm)	# branches per plant	Seed weight/ plant	# Pods/ plant	Pods Yield kg ha
			Long rains			
Rhizobium	65.0	21.8	4.2	4.6	7.2	1888
FYM	69.0	23.5	4.4	4.1	7.7	1750
NIL (control)	63.0	21.1	4.2	5.1	7.3	1710
DAP	47.0	22.4	4.5	5.7	10.0	2570
NPK	57.0	22.3	4.5	4.6	8.6	2090
$LSD_{0.05}$	7.1	NS	NS	NS	1.0	NS
			Short rains			
Rhizobium	80.0	21.6	4.9	6.4	11.9	2770
FYM	65.0	29.9	4.8	5.7	11.9	2289
NIL (control)	73.0	22.4	4.9	5.5	11.1	2489
DAP	61.0	25.9	5.1	7.0	9.4	2934
NPK	85.0	25.9	5.1	6.7	11.1	2978
$LSD_{0.05}$	NS	1.9	NS	NS	NS	NS

Rhizobium = *Rhizobium* inoculant, FYM = farmyard manure, Nil - no input applied, DAP = Diammonium phosphate fertilizer (18-46-0), NPK = compound fertilizer (20-20-0).