Sources of Pod Yield Losses in Groundnut in the Northern Savanna Zone of Ghana

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Abstract

Groundnut (*Arachis hypogaea* L.) has gained prominence as a food and cash crop due to its increasing importance, both in the domestic and export markets. Its products, such as oil and cake, are for both domestic and industrial uses. However, farm level yields in Ghana have remained as low as 800 kg/ha compared to developed countries of more than 3,000 kg/ha. Variation in the yield of the groundnut crop has been found to be a genetic trait influenced by environment or the interaction of both. In order to identify the sources responsible for these low yields on farmers' fields, and to be able to advise them to increase their yields, a field experiment was conducted in 2007 and 2008 on a savanna soil at Nyankpala, involving three groundnut varieties, in a split-plot design replicated four times. The varieties *(Chinese, Manipinta* and *Nkatie-Sari)* were the main factor and three harvesting stages (at maturity of each variety, 1 week after and 2 weeks after the first harvest) were the sub-plots. Pod yields were between 2,500 kg/ha and 3,100 kg/ha for the three varieties in both years at physiological maturity, which were higher than yields from the subsequent harvest dates. The decline in pod yield when harvesting was delayed beyond physiological maturity was attributed to insect infestation of the pods, sprouting of the nuts in the soil and difficulties in harvesting, resulting in most of the nuts either not harvested or physically damaged. The *Chinese* variety had more sprouted nuts as well as nuts left not harvested in the soil probably due to its spreading nature compared to *Manipinta* and *Nkatie-Sari,* which can be described as the bunch types. *Nkatie-Sari* significantly gave the highest pod yield at each stage of harvest than the other varieties. It is advisable that farmers plant improved varieties, making sure they harvest at physiological maturity, before the onset of the dry season, in order to obtain optimum pod yields of the groundnut,.

Introduction

It has been reported that over 90% of the world groundnut (*Arachis hypogaea* L.) crop is produced in developing countries, and roughly 67% of the quantity produced is used for oil (FAO, 2006). This makes groundnut the second most important source of vegetable oil after soybean (Freeman *et al.*, 1999). The world production of unshelled groundnut is estimated to be 35.9 million metric tonnes (FAO, 2006) annually, with India being the largest producing country in the world (Pandy, 1993). Groundnut is an important subsistent food crop throughout the tropics. Although it is a warm temperature crop, varieties exist that are adapted to altitude of 1,500 m.

In Ghana, groundnut remains the most popular and widely cultivated legume because of its adaptation to the climatic conditions, as well as limited field pest problems (Mills, 2000). As a good source of food and oil, groundnut also provides adequate amount of protein, fat and carbohydrates for both human and livestock. The haulms are used as fodder for feeding livestock during the dry season, especially in northern Ghana. The pods after shelling are used as mulching material for moisture conservation and also to add nutrient to the soil when decomposed (Ayanlaga & Sanwo, 1991). Being a nitrogen-fixing legume, groundnut enriches the soil by fixing atmospheric nitrogen without draining the non-renewable energies and without upsetting the agro-ecological balance (Reddy & Kaul, 1986).

Despite its importance, groundnut yield of 800 kg/ha obtained in Ghana is low compared to a yield of about 3000 kg/ha in the developed countries such as the United States (FAO, 1994). Initially, the low groundnut yield in Ghana was attributed to the low yielding genetic potential of the varieties available at that time. This constraint is being addressed by the National Agricultural Research Systems (NARS) as there are now several high yielding, disease and heat tolerant released groundnut, varieties such as *Edorpo-Munika* and *Nkatie-sari* (Frimpong *et al.,* 2006; Padi *et al.*, 2006). However, with the release of these high yielding groundnut varieties to farmers to increase productivity, it has been observed that groundnut yields on farmers' fields are still lower than expected. Other reasons for this low yields, which have also been identified and are being addressed include pest and disease infestations, and climatic and adverse weather conditions affecting the crop (SARI, 2000). What seem to be lacking, which may be responsible for the current low groundnut yields, are the farmers' attitude and delay in execution of some cultural and agronomic operations on their fields.

Among the activities not timely executed is harvesting of groundnuts. It has been observed that groundnut is always harvested several weeks after physiological maturity, which is a common practice in Ghana, as farmers are always engaged in both farm and off-farm activities (RELC, 2000). Delayed harvesting of groundnut may reduce grain yield and quality. However, there is little information on the effect of the delay in harvesting on the pod yield of groundnut. It was in the light of this that three varieties of groundnut were subjected to different harvesting dates, starting from physiological maturity, to assess the grain yield at each harvest and grain quality with time. The objectives of the study were, therefore, to 1. determine the pod yield of three groundnut varieties under delayed harvesting, and 2. identify and estimate the losses in groundnut yield due to delay in harvesting.

Materials and methods

Study site

The experiment was conducted on the Research Farm of the Savanna Agricultural Research Institute (SARI), Nyankpala, during the 2007 and 2008 cropping seasons. Nyankpala is located on latitude 9° 25" N and longitude 1° 00'W, with an altitude of 183 m above sea level. The climatic condition of the site is semi-arid with annual average rainfall of 1,200 mm. The average daily temperature ranges from a minimum of 26 °C to a maximum of 39 °C, with a mean of 32 °C. The vegetation of the site is mainly grassland regrowth, which is interspersed, with shrubs and short non-canopy forming economic trees such as the shea (*Vitellaria paradoxa*) and dawadawa (*Parkia biglobosa*). The soil of the site is well drained Voltaian sandstone, locally known as the Tingoli series and classified as ferric luvisol (FAO/UNESCO, 1977).

Experimental design and treatments

The experiment was conducted in a split-plot arrangement of treatments in a randomized complete block design with four replications. The main plot was made up of three groundnut varieties while sub-plots were the three harvesting dates. The harvesting dates were (i) at physiological maturity indicated as H1, (ii) 1 week after the first harvest (i.e. 1 week after physiological maturity) indicated as H2, and (iii) 1 week after the second harvest (i.e. 2 weeks after physiological maturity) indicated as H3. The test varieties were *Chinese*, a spreading or creeping type maturing in 90 days, *Manipinta*, a semi-erect type maturing in 120 days and *Nkatie-Sari*, erect or bunch type, maturing in 110 days. The seeds were obtained from the Groundnut Improvement Program of SARI.

Land preparation, planting and weed control

The land was ploughed and later harrowed to obtain a fine tilth each year. The groundnut varieties were planted on 16th July 2007 and 20th July 2008 with a spacing of 50 cm between rows and 15 cm within rows. Weeds were controlled using the hand hoe.

Harvesting

Harvesting was carried out at each stage by either digging, using a hand-held hoe, when the soil was dry and by uprooting the plant by hand when the soil was wet. Harvesting was carried out weekly with the first harvest at physiological maturity.

Data collection

Data collected included pod yield, pods physically damaged during harvesting, pods damaged by insects, pods gleaned after harvesting, pods that sprouted, and 100-seed weight.

Pod yield. The harvested pods of groundnut from each plot were sun-dried for 2 weeks. The unshelled pods at each harvesting stage after drying were separated into four categories: pods damaged by insect, physically damaged pods during harvesting, sprouted or germinated pods and unaffected (good) pods. The total of each of these was weighed per plot and converted into per hectare basis. The weight of the good pods, which were not affected physically, not damaged by insects and not sprouted was considered as the actual pod yield at each harvest. After shelling the groundnut, the seed weight for each variety was determined for a sample of 100 oven-dried seeds.

Gleaning after harvesting. At each harvest, pods left in the field were gleaned. These were collected and weighed according to varieties and harvesting dates. The quantity of groundnut gleaned constituted part of the losses in groundnut yield.

Insect damaged pods, sprouted pods and physically damaged pods. The groundnut pods, which were harvested according to varieties and dates, were separated into those physically damaged pods during harvesting, insect infested pods and those that germinated *in situ* (sprouted pods). These were each weighed using an electronic scale.

Data analysis

Data collected were subjected to analysis of variance (ANOVA) to establish treatment and the interactions effect on the parameters measured or calculated. Statistical analyses were performed with the Statistical Program, GENSTAT. Groundnut varieties and harvesting dates were treated as fixed effects, and year and replication were treated as random effects. Main effects and all interactions were considered significant when $P \leq 0.05$. Means were separated using the least significant difference (LSD) at 5% level of probability only, when the F-test showed a significant difference.

Results and discussion

In each year, variety × harvesting date interactions were statistically significant for all parameters measured or calculated, indicating a genotypic difference in the response of the three groundnut varieties to harvesting dates. Additionally, there were differences between seasons. Thus, data were presented for each variety at each harvesting date and separately for each year.

In general, groundnut yield varies depending on the soil, climatic conditions, cultivar characteristics, and level of management (Tindall, 1988). However, delay in harvesting of the crop also exposes it to environmental hazards, which reduces yield leading to further yield variations. Field observations from the planting of the groundnut crop to harvesting indicated and confirmed the suspicion that significant yield losses occur when the crop is left not harvested for a long time after physiological maturity (SARI, 2007). The consequence of this action led to the destruction of the crop by insect pests such as termites. The nuts of some of the groundnut varieties also sprouted under the soil when harvesting was delayed beyond physiological maturity. At this stage, harvesting of the crop by uprooting by hand became impossible as the soil became dry and hard. This situation left no other alternative than to harvest by digging using hand hoe which equally becomes difficult due to the dry weather conditions. As a result of digging the dry soil, most of the nuts were either left in the soil or were physically damaged by the hoe.

Groundnut pod yield as affected by delay in harvesting

On average, pod yields were slightly higher in 2007 than 2008. In both years, pod yields for all varieties were highest at physiological maturity and lowest at the final harvest (Table 1). In general, pod yields of the three varieties tended to decrease with delay in harvesting after physiological maturity probably because of the adverse effects of dry weather on the crop as a result of delay in harvesting. The nuts of some of the groundnut varieties also sprouted under the

TABLE 1

Pod yield (kg/ha) of three varieties of groundnuts as affected by delay in harvesting in 2007 and 2008

	Harvesting date					
	2007			*2008*		
Variety	*H1*	*H2*	*H3*	*H1*	*H2*	*H3*
Chinese	2501	2406	1625	2410	2260	1601
Manipinta	2938	2250	1938	2805	2211	1921
Nkatie-Sari	3156	2625	2313	3085	2560	2306
LSD (0.05)	326	211	216	310	205	209
CV%	15.7			14.2		

H1 = harvest at physiological maturity, H2 = a week after physiological maturity, H3 = two weeks after physiological maturity.

soil when harvesting was delayed beyond physiological maturity. This, therefore, resulted in large quantities of pods left in the soil, pods damaged by insects and physically damaged pods. Averaging over varieties, pod yield declined by 18% and 42% when harvesting was delayed for 1 and 2 weeks after physiological maturity, respectively.

At physiological maturity, *Nkatie-Sari* gave the highest pod yield of 3156 and 3085 kg/ha in 2007 and 2008, respectively, but these were not significantly different from the yields obtained by *Manipinta* at physiological maturity in those years. Nevertheless, *Chinese* obtained significantly the least pod yields of 2501 and 2401 kg/ha at physiological maturity in 2007 and 2008, respectively. The yield reduction in the *Chinese* variety may be due to the high amount of physically damaged pods and sprouted pods as reported pod yield values involved only healthy pods. The variations in pod yields in this study agree with the findings of Onwueme and Sinha (1991) who reported that the average yield of groundnut in Ghana is in the range of 600–4000 kg/ha and it is dependent on cultivar characteristics.

At the second harvest, although there was a decline in pod yields for all the varieties in both years, differences among the varieties were not significant. Nonetheless, at the third harvest (2 weeks after physiological maturity), *Manipinta* and *Chinese* had similar pod yields, which were both significantly lower than that of *Nkatie-Sari*. Thus, *Nkatie-Sari* still out-yielded both *Manipinta* and *Chinese,* even when harvesting was delayed for 2 weeks after physiological maturity, indicating that either it is genetically a high yielding variety or it can withstand some of the environmental hazards even if harvesting is delayed for 2 weeks. According to Tindall (1988), groundnut yield varies depending on the soil, climatic conditions, cultivar characteristics, and level of management. Variation in the yield of different varieties of groundnut has, therefore, been found to be a genetic trait, influenced by environment or the interaction of both (Ahmad & Mohammad, 1997; Virk *et al*., 2005 and Abdullah *et al*., 2007).

Hundred seed weight of groundnut as affected by delay in harvesting

In both years, *Manipinta* had significantly higher hundred seed weight (heavier seeds) than *Chinese* and *Nkatie-Sari* at each harvesting date (Table 2). In addition, the seed weight of *Nkatie-Sari* was significantly higher than that of *Chinese,* which recorded the lowest seed weight regardless of date of harvesting. Similar trend was observed in both 2007 and 2008. The bigger nuts of *Manipinta* could be responsible for its higher hundred seed weight than the *Chinese* variety which had the smallest seed. Mean hundred seed weight is an expression of the amount of dry matter allocated to the seed development by treatments which is attributed to plant or varietal factors (Karkannavar *et al.,* 1991). However, seed weight of all varieties tended to increase as harvesting was delayed.

Quantities of groundnut damaged by Insect pest

In both years, analysis of the field observation at every stage of harvesting revealed that the damage done to groundnut pods by insects before harvesting was

TABLE 2
Effects of delay in harvesting of groundnut on 100 seed weight (g) in 2007 and 2008

	Harvesting date					
	2007			2008		
Variety	*H1*	*H2*	*H3*	*H1*	*H2*	*H3*
Chinese	22.85	21.93	24.73	22.65	20.63	23.78
Manipinta	34.37	38.85	42.77	32.62	36.58	39.86
Nkatie-Sari	28.27	30.04	36.64	28.01	29.68	35.65
LSD (0.05)	3.33	3.24	4.63	4.21	2.95	3.02
CV%		7.5			7.2	

H1 = harvest at physiological maturity, H2 = a week after physiological maturity, H3 = two weeks after physiological maturity.

mainly due to termites. The results showed that harvesting at physiological maturity gave the lowest quantities of groundnut pods damaged by termites than the subsequent harvesting dates for all the varieties in both years (Table 3). Insect damage to pods tended to increase with delay in harvesting in both years probably due to an increase in insect population with time.

Comparably, at every stage of harvest, *Nkatie-Sari* had significantly the lowest quantity of pods damaged by termites than *Chinese* and *Manipinta* in both years. Additionally, at physiological maturity, *Manipinta* had the highest quantity of pods damaged by insects followed by *Chinese.* However, the quantities of pods of *Manipinta* and *Chinese* damaged by insects were not significantly different at physiological maturity. Nonetheless, as harvesting was delayed for 1–2 weeks, insect damage of pods was consistently more severe on *Manipinta* than on *Chinese* and *Nkatie-Sari* in 2007 and 2008.

Insects are the most destructive group of pests that attack cultivated crops, which result in low yield and poor quality of the grains. The rate of pest build-up depends on the availability of food, number of generation per season and the temperature during

TABLE 3
Effect of delay in harvesting on insect damaged of groundnut pods (kg/ha) in 2007 and 2008

	Harvesting date					
	2007			2008		
Variety	*H1*	*H2*	*H3*	*H1*	*H2*	*H3*
Chinese	7.70	18.58	19.50	6.15	18.10	18.96
Manipinta	9.49	24.53	28.87	6.12	23.14	26.24
Nkatie-Sari	2.31	12.95	15.97	4.20	11.02	13.60
LSD (0.05)	2.10	2.16	2.82	1.15	2.03	1.68
CV%	27.8			28.0		

H1 = harvest at physiological maturity, H2 = a week after physiological maturity, H3 = two weeks after physiological maturity.

development (Feakin, 1973). Insects such as termites feed and destroy shoots, flowers and young seedlings, and also, in some cases, they cause scarification of pod, which weakens the shells and makes them liable to crack during harvesting leading to further insect and disease infestations (SARI, 2005). The lower quantities of *Nkatie-Sari* nuts infested by termites could be due to the thickness of its shells. Comparably, the shells of *Nkatie-Sari* appear to be thicker than those of *Manipinta* and *Chinese*.

Quantities of groundnut physically damaged at harvest

Groundnut is harvested mostly either by uprooting the plant by hand or by digging the plant out from the soil, using the hand hoe, as mechanical harvesters are not available for use by farmers in Ghana. Physical damage of the pods was significantly affected at all harvesting dates (Table 4). Over the years, similar to the effect of insect damage to pods, physical damage to the pods on average tended to increase with delay in harvesting probably due to the drying of the soil which made digging and pulling out of pods very difficult. Thus, many pods of each variety got damaged. Damage to the nuts may favour invasion by the fungus *Aspergillus flavus,* which produces toxic secondary metabolites called aflatoxins.

At physiological maturity in both years, quantity of damage pods due to harvesting was significantly highest for *Chinese* followed by *Manipinta* and then *Nkatie-Sari.* The latter two varieties had similar quantities of pods physically damaged during harvesting. Across years, pod damaged when harvesting was done at physiological maturity ranged between 2 and 7 kg/ha but this increased to a range of 17–18 kg/ha, when harvesting was delayed for 2 weeks after maturity. It is worthy of note that similar to physical damaged pods, *Chinese* and *Manipinta* also had higher levels of pods damaged by insects over the years when compared with *Nkatie-Sari.*

It has been found that harvesting of the spreading type of groundnut by digging results into some of the nuts being damaged by the hoe (SARI, 2007). This is because it is difficult to estimate how deep the nuts are in the soil as at every node of each branch of the crop, there are pegs that produce nuts. It was,

TABLE 4

Effect of delay in harvesting on physical damage of pods (kg/ha) of three varieties of groundnut during harvesting in 2007 and 2008

	Harvesting date					
	2007			*2008*		
Variety	*H1*	*H2*	*H3*	*H1*	*H2*	*H3*
Chinese	6.70	14.89	18.87	5.25	14.52	18.02
Manipinta	4.83	15.89	18.86	3.92	14.67	17.96
Nkatie-Sari	2.06	14.53	17.89	1.98	14.14	17.36
LSD (0.05)	1.34	NS	NS	0.86	NS	NS
CV%	28.9			28.5		

HD1=harvest at physiological maturity, HD2 = a week after physiological maturity, HD3 = two weeks after physiological maturity; NS = not significant at the 5% level of probability.

therefore, not surprising that *Chinese,* being one of such varieties, had significantly larger quantities of damaged pods. When harvesting was delayed for 1–2 weeks after physiological maturity, quantities of physical damaged pods were similar for the three varieties.

Quantities of groundnuts sprouted before harvesting

Pre-harvest sprouting in groundnut seeds is undesirable since it leads to substantial loss of seeds, both in quantity and quality. The lowest quantity of *in situ* germinated nuts (sprouted nuts) was recorded when groundnut was harvested at physiological maturity for all varieties (Table 5). The quantities of sprouted nuts tended to increase with delay in harvesting for all varieties in 2007 and 2008.

Among the three varieties, *Chinese* had the highest quantities of sprouted nuts in both years when harvesting was delayed. On average, the quantity of sprouted nuts of *Chinese* significantly increased from about 2 kg/ha to 16 and 18 kg/ha, as harvesting was delayed for 1 and 2 weeks, respectively, after physiological maturity. The trend was similar in both years. Sprouting of pods at physiological maturity and, thereafter, was minimal with *Nkatie-Sari* in each year. The highest value of sprouted pods in *Chinese* was probably due to the fact that *Chinese* seed lacks dormancy and, therefore, has the tendency to germinate *in situ* after physiological maturity compared to the other two varieties (SARI, 2007; Asibuo *et al*., 2008). Nevertheless, a short period of seed dormancy is necessary to reduce these losses. Lack of dormancy resulting in sprouting of nuts immediately after physiological maturity has been observed in Chinese variety, and could therefore, be a genetic and not environmental factor (RELC, 2006). Moreover, Asibuo *et al*. (2008) reported that seed dormancy in groundnut is controlled by monogenic inheritance, with dormancy dominant over non-dormant.

Quantities of groundnuts pods gleaned after harvesting

Some quantities of groundnuts were gleaned after first harvesting of the crop. For

TABLE 5

Effect of delay in harvesting on sprouting of the pods (kg/ha) of three groundnut varieties in 2007 and 2008.

	Harvesting date					
	2007			*2008*		
Variety	*H1*	*H2*	*H3*	*H1*	*H2*	*H3*
Chinese	1.83	16.53	18.28	1.62	16.28	17.66
Manipinta	0.38	0.89	2.37	0.24	0.78	2.20
Nkatie-Sari	0.01	0.59	1,98	0.01	0.36	1.86
LSD (0.05)	0.27	0.12	0.68	0.16	0.06	0.72
CV%	53.4			52.9		

HD1 = harvest at physiological maturity, HD2 = a week after physiological maturity, HD3 = two weeks after physiological maturity.

all the varieties, the quantities of the nuts gleaned increased by 81–85% after the harvest at physiological maturity (Table 6). At every stage of harvest, the *Chinese* variety had significantly higher quantities of groundnut gleaned than *Manipinta* and *Nkatie-Sari*. However, the quantities gleaned for *Manipinta* and *Nkatie-Sari* were similar at each harvesting date in both years. It has been documented that dry soil makes harvesting of pods difficult leading to some of the nuts in the soil left not harvested (Onwueme & Sinha, 1991). Among the three varieties tested, the *Chinese* variety recorded the highest losses of an average of 25 kg/ha, as obtained from the pods gleaning at 2 weeks after physiological maturity. This may be due to the difficulties associated with the creeping or spreading variety.

Conclusions and recommendations

For all the groundnut varieties tested, harvesting at physiological maturity gave the highest pod yields than the subsequent harvesting dates, indicating that harvesting at physiological maturity, especially when the soil still contains little moisture, will help minimize pod yield losses in groundnut. Among the varieties, *Nkatie-Sari* gave significantly higher pod yields at each stage of harvesting than *Chinese* and *Manipinta,* making it the highest yielding variety.

Apart from the pod yield differences at each stage of harvesting among the varieties, which is genetic, other factors identified are environmental, which are linked to the delay in harvesting of the crop. These are insect (termites) infestation of the pods, sprouting of the pods in the soil due to lack of seed dormancy and physically damaged pods during harvesting. As a result of delay in harvesting of the crop, which was always at the end of the rainy season, it became difficult to uproot the plants by hand since the soil is dry and hard. This makes farmers resort to harvesting by digging, using hand hoe, which also results in most of the pods being left in the soil not harvested, as evidenced by the quantity of pods gleaned from the field. Thus, soil moisture-deficit may increase the pod losses.

Among the varieties tested, *Chinese* was

TABLE 6

Effect of delay in harvesting on total pods (kg/ha) of three groundnut varieties gleaned after harvesting in 2007 and 2008.

	Harvesting date					
	2007			*2008*		
Variety	*H1*	*H2*	*H3*	*H1*	*H2*	*H3*
Chinese	4.11	15.42	26.25	3.90	14.86	25.02
Manipinta	1.89	12.70	13.17	1.72	11.66	12.86
Nkatie-Sari	1.50	11.97	12.39	1.42	10.98	11.24
LSD (0.05)	0.92	0.82	1.91	0.86	0.75	1.82
CV%	25.0			25.1		

H1 = harvest at physiological maturity, H2 = a week after physiological maturity, H3 = two weeks after physiological maturity..

the worst variety in term of pods remaining in the soil not harvested probably because it is the creeping or spreading type compared to *Nkatie-Sari* and *Manipinta,* which are the erect (bunch) and semi-erect types, respectively. It also had the largest quantity of sprouted nuts due to lack of seed dormancy. It seems soil moisture at the time of harvest, together with the type of cultivar, play an important role in pod losses. It is, therefore, recommended that, for farmers to obtain optimum pod yields with high quality seeds, they should grow the available improved groundnut varieties and make sure they harvest at physiological maturity before the onset of the dry season in northern Ghana.

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References

Abdullah T., Rahianna A. A., Hardaningsh S. and **Rozi F.** (2007). Increasing groundnut yield on dry land Alfisols in Indonesia. *J. SAT agric. Res.* **5** (1).

Ahmad N. and **Mohammad R.** (1997). Evaluation of Promising groundnut (*Arachis hypogyea*) varieties for yield and other characteristics. *Crop Soil Sci*. 251 pp.

Asibuo J. Y., Akromah R., Safo-Kantanka O., Adu-Dapaah H., Kofi O. D. S. and **Agyeman A.** (2008). Inheritance of fresh seed dormancy in groundnut. *Afr. J. Biotechnol.* **7**: 421–424.

Ayanlaga S. A. and **Sanwo J. O.** (1991). Management of soil organic matter in the farming system of the low land humid tropic of West Africa. *Rev. Soil Technol.* **4** (3): 265–277.

FAO (1994). *Food and Agricultural Organization Production Year Book*. FAO, Rome, Italy.

FAO (2006). *Food and Agricultural Organisation Production Year Book*. FAO, Rome, Italy.

FAO/UNESCO (1977). *Soil Map of the world*, Vol. 6, Africa. FAO, Rome. 299 pp.

Feakins S. D. (1973). Pests control in groundnuts. *Pans manual No*. 2. Center for overseas Pests Research, Foreign and Commonwealth Office Overseas Development Administration, London. pp. 21–79.

Freeman H. A., Nigam S. N., Kelly J. G., Ntare B. R., Subrahmanyam P. and **Boughton D.** (1999). *The Word Groundnut Economy: Facts, Trend and outlook*. ICRISAT, Hyderabad Andhra Pradesh, India.

Frimpong A., Padi, F. K. and **Kombiok J.** (2006). Registration of foliar disease resistant and high yielding varieties; ICGV 920099 and ICGV 90084. *International Arachis News Letter No. 26.*

Karkannvar J. C., Venugopal R. and **Goud J. V.** (1991) Inheritance and linkages Studies in Cowpea (*Vigna unguiculata* L. Walp). *Indian J. Gen*. **51**: 203–207.

Mills O. (2000). *Survey of prevalent Weeds and Management Practices on Yield of Groundnut in Northern Ghana.* (BSc. Dissertation.) Agronomy Department, U. D. S Tamale. 1–12 pp.

Onwueme I. C. and **Sinha T. D**. (1991). *Field Crop Production in Tropical Agriculture*. Technical Center for Agricultural and Rural Co-operation. The Netherlands. pp. 321–336.

Padi F. K., Frinpong A., Kombiok J., Salifu A. B. and **Marfo K. O.(**2006). Registration of Nkatie-sari. *Crop Sci.* **46**: 1396–1397.

Pandy B. P. (1993). *Tropical crops. A text book of economic botany*. Macmillan, London, UK. 501 pp.

RELC (2000). *Research- Extension-Linkage Committee (RELC) .Annual Report.*

RELC (2006). *Research- Extension-Linkage Committee (RELC) .Annual Report*.

Reddy L. J, and **Kaul A. K**. (1986) *Status and prospects of groundnut in Bangladesh*. Bangla Argil Press Dhaka, pp. 1–51.

Reddy T. Y., Reddy V. R. and **Anbumozhi V.** (2003). Physiological responses of groundnut (*Arachis hypogaea* L.) to drought stress and its amelioratio*n: a* critical review. *Plant Growth Regulation*. **41**: 75–88.

SARI (2000). Crop protection Programme of the Savanna Agricultural Research Institute. *SARI Annual Report, 1999*.

SARI (2005). Legumes Breeding Programme of the Savanna Agricultural Research Institute. *SARI Annual Report*, 2004.

SARI (2007). Legumes Breeding Programme of the Savanna Agricultural Research Institute. *SARI Annual Report*, 2006.

Tindall H. D. (1988). *Vegetables in the Tropics*. Mac Millan Education Ltd. pp. 250–264.

Virk A. S., Kaul J. N., Bhangoo B. S. and **Singh A.** (2005) Influence of planting technique and plant population on Biology and pod productivity of summer groundnut varieties. *Res. Crops* **6** (1): 173–174.