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Research Article

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Effect of Harvesting Stages on Seed Quality Characteristics of Three Soybean (Glycine Max (L) Merrill) Varieties

Osei Tutu Isaac[1], Ben Kwaku Banful[1], Stephen Amoah[2], Samuel Apuri[3], Emmanuel Amomba Seweh[4]

[1]Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
[2]Legumes and Oil Improvement Division, CSIR-Crops Research Institute, Kumasi, Ghana.
[3]Departments of Ecological Agriculture, School of Art and Applied Sciences, Bolgatanga Polytechnic, Bolgatanga.
[4]Department of Agricultural Engineering, School of Engineering, Bolgatanga Polytechnic, Bolgatanga, Ghana.

Abstract A research study was conducted to determine the most appropriate stage of harvesting soybean, with minimal effects on seed quality characteristics. The field experiment was conducted at the Research fields of CSIR-Crops Research Institute at Fumesua, Kumasi Ghana ($01^0$36'W; $06^0$43'N) with the treatment of harvesting soybean pods at physiological maturity, one and two weeks after physiological maturity. Physiological maturity was determined when 90% of the pods on the plant turned brown. The study revealed that soybean varieties harvested at physiological maturity recorded the highest seed yield as compared to other harvesting stages. Delaying harvesting by one and two weeks after physiological maturity resulted in seed yield loss of 49.4% and 63.2% respectively. Varieties harvested at physiological maturity registered high germination percentage, vigour and fat content while those harvested two weeks after physiological maturity had the lowest. Moreover, none of the varieties harvested at physiological maturity stage encountered shattering loss. However, varieties harvested one and two weeks after physiological maturity resulted in 20 and 31.22% shattering loss, respectively, of the total seed weight. The results obtained indicated that for good yield and seed quality, soybean pods should be harvested at physiological maturity.

Keywords Soybean, harvesting stages, physiological maturity, seed quality.

Introduction

Marcos-Filho *et al.* (1994) posited that harvesting time was a critical step in soybean seed production because the seed deterioration actually began either in the field, during harvesting or after harvesting [1]. Soybean seed is structurally weak, inherently short-lived and easily subject to damage [2-3]. Seed yield and quality largely depends on the stage of maturity [4]. Soybean maturity depends on the variety and requires timely harvesting to reduce excessive yield losses [5]. In early harvested seed crop, the seed quality will be very poor due to more number of immature and undeveloped seeds, while in delayed harvesting, seed quality are affected on account of field weathering [6]. When beans are ready for harvest and are subjected to alternating periods of wet and dry weather, pre-harvest or shattering loss can be high [7]. The seed reaches its maximum dry weight at physiological maturity [8].

Physiological maturity is a point where there is stabilization of dry matter translocation to the seed [1]. If the seeds are retained on mother plant after physiological maturity, physiological changes in seed may lead to formation of hard seeds or off colour seeds in pulse crops [8]. According to Narayan *et al*., (1988a), shrinking and breaking of seeds are some of the physical changes that occurred in soybean seeds after harvesting. Narayan *et al.* (1988b) added that physical, chemical and biochemical alterations may occur in soybeans, depending on

conditions and storage duration [9-10]. Seeds rich in lipids have limited longevity due to their specific chemical composition. Soybean seed after harvesting demands special attention due to its oil content, otherwise processes may occur that lead to the loss of germination ability and seed viability [11].
Several studies on soybean harvesting time have been done but unfortunately the emphasis has been on grain and not seed. Consequently, farmers are continually faced with the challenge of loss of seed viability and poor germination when the next production period gets underway. Therefore, the study was designed to determine the most appropriate harvesting stage of soybean with minimal effects on seed quality characteristics. Specifically, the objectives were to determine the effect of stage of soybean harvest on seed yield, germinability, vigour and chemical qualities of the three varieties.

Materials and Methods
The study comprised of field experiment and laboratory analyses. The field experiment was conducted at the CSIR-Crops Research Institute (CRI) at Fumesua, Kumasi Ghana ($01^0$36'W; $06^0$43'N). The laboratory analyses were carried out at the Department of Biochemistry, Department of Horticulture and Department of Crop and Soil Sciences, KNUST, Kumasi. Seeds of three varieties of soybean (Nangbaar, Anidaso and Jenguma) were procured from CSIR – Crops Research Institute and CSIR – Savanna Agricultural Research Institute (CSIR-SARI). The maturity classes of Nangbaar, Anidaso and Jenguma are early (≤100 days), medium (101-110 days) and late maturing (110-115 days), respectively [12].
Experiment 1: The field experiment was set up in a 3 x 3 factorial arrangement in Randomized Complete Block Design (RCBD) with three replications. The first factor was variety at three levels (Nangbaar, Anidaso and Jenguma) whiles the second factor was stage of harvest also at three levels (harvesting at physiological maturity (H_0), one week after physiological maturity (H_1) and two weeks after physiological maturity (H_2). The land was manually prepared using the zero tillage technology. Seeds were planted in ten rows in each plot of 5 m long at spacing of 60 cm between rows and 10 cm within rows. Distance between replicates was 1 m. Three seeds were planted per hill and thinned to two plants per hill at two weeks after planting. No soil amendment or fertilizer was applied. Weeds were effectively controlled during the growing period. Monitored spraying was carried out at four and six weeks after planting with Lambda Super 2 SEC to control insect pests. All the good agronomic practices were observed.
Seeds were harvested at three different stages; harvesting at physiological maturity (H_0), and at one and two weeks after physiological maturity (H_1 and H_2 respectively). Physiological maturity harvesting was carried out when 90% of the pods on the plant turned brown [5]. Pods harvested at physiological maturity were further dried for one week before threshing manually. No further drying was however done with pods harvested one and two weeks after physiological maturity. Following each harvest, seed yield per two rows and percentage shattering loss of seeds were determined.
Seed Yield: Two rows were used to evaluate seed yield of each varietal harvesting stage. A total of two hundred and four plants were used. After harvesting, threshing was done to remove the seeds from the pods. Seeds obtained were then weighed to determine the seed yield (g).
Percentage Seed Shattering Loss: Shattering loss of seed was determined by counting all loose beans and beans in loose pods on the ground [7]. The number of seeds that shattered was collected on a daily basis after observing first shattering on the field. The number of seeds that shattered was weighed with analytical balance and the percentage shattering loss determined from total seed yield.
Experiment 2: Harvested seeds obtained were then used for further laboratory analyses to determine germination percentage, seed vigour (seed conductivity test), moisture content, protein and oil content.
Determination of Germination Percentage: Germination test was carried out according to ISTA (2007) [13]. For each treatment, 400 seeds from the pure seed fraction of a purity test were used to conduct the germination test. The seeds were arranged in four replicates of 100 each on a counting board and planted in a level layer of moist sand in a perforated container. On day eight, each replicate was examined and evaluated separately. Seedlings and seeds were counted and grouped into normal and abnormal seedlings, fresh ungerminated seeds, hard and dead seeds. The percentage germination indicates the proportion of seeds which produced seedlings classified as normal under the conditions and within the period specified. Germination percentage is determined using Equ 1, [13].

$$\text{Germination } \% = \left[\frac{\text{Number of germinated seeds}}{\text{Number of total seeds planted}}\right] \text{x } 100 \qquad \text{.....Equ 1}$$

Determination of Seed Vigour: Conductivity test was used in determining the vigour of the seeds. Four replicates of 50 seeds of each treatment were drawn at random and tested for electrical conductivity. Seeds were

placed in Erlenmeyer flasks containing 75 ml ultra pure deionized water equilibrated to 25 °C, then maintained at 25 °C for 24 h. After 24 h of soaking, the flasks was swirled for 10-15 sec and seeds then taken out of water with a clean forceps. An electrical conductivity dip cell was inserted into the seep water until a stabilized reading was achieved and recorded. The mean of the two control flasks (sterilized distilled water) when measured served as background reading. Conductivity was calculated using Equ 2, [13].

$$\text{Conductivity, } (\mu S\, cm^{-1} g^{-1}) = \left[\frac{\text{Conductivity reading} - \text{background reading}}{\text{Weight (g) of replicate}}\right] \quad \text{.....Equ 2}$$

Determination of Moisture Content: The low constant temperature oven method (AOAC, 2007) was used to determine the moisture content of the seeds. Empty glass crucible was thoroughly washed, cleaned and dried for one hour at 130 °C and placed in desiccator to cool. The empty crucible and its cover were then weighed before and after filling. About 5 g milled soybean seed from each sample was weighed and transferred into a previously weighed empty glass crucible and placed in an oven maintained at a temperature of 105 °C and dry for 5 h. Four replicates were taken. At the end of the prescribed period, the container was covered and removed from the oven and allowed to cool in desiccator to room temperature. After cooling, the container with its cover and content was reweighed and figures recorded. Loss in weight was calculated as percentage moisture content using Equ 3, [14].

$$\%\ \text{Moisture (wt)} = \left[\frac{\text{weight of wet sample} - \text{weight of dry sample}}{\text{weight of wet sample}}\right] \text{x } 100 \quad \text{.....Equ 3}$$

Determination of Crude Fat Content: The sample used for the moisture content determination was transferred into a paper thimble, labeled and put in a thimble holder for the crude fat determination [14]. 150 mL of petroleum spirit was poured into a pre-weighed 500 mL round bottom flask and assembled on a semi-continuous soxhlet extractor and refluxed for 16 h. The hexane was recovered after removing the paper thimble from the thimble holder and the flask containing the fat heated for 30 min in an oven at 103^0 C to get rid of the residual hexane. The flask containing the fat was re-weighed after being cooled in a desiccator [14]. The increase in weight was calculated as percentage crude fat as shown in Equ 4.

$$\%\ \text{Fat} = \left(\frac{\text{weight of fat}}{\text{weight of sample}}\right) \text{x } 100 \quad \text{.....Equ 4}$$

Determination of Protein Content

The protein content was determined using the Kjeldahl method in three steps: digestion, neutralization and distillation, and titration [14].

Digestion: About 2 g of the sample was weighed into a digestion flask and mixed with 25 mL of concentrated H_2SO_4, selenium catalyst and few anti-bumping agents. The content of the flask was digested by heating in a fume chamber till the colour of the solution turned clear.

Neutralization and Distillation: After the digestion has been completed, the digestion flask was allowed to cool and the solution transferred into a 100 mL volumetric flask and the volume made up to the 100 mL mark with distilled water. The distillation apparatus was flashed out with water and 10 mL of digested sample transferred into the distillation apparatus. The solution was neutralized with 18 mL NaOH and boiled under distillation water in a steam generator. Circulation was allowed for about 10 min. A conical flask was filled with 25 mL of 2% boric acid and 3 drops of mixed indicator (methylene blue and methylene red) added. The conical flask and its content were placed under the condenser in a position where the tip of the condenser was completely immersed in solution for 10 min and end of condenser washed with distilled water.

Titration: The nitrogen content was then estimated by titrating the ammonium borate formed in the conical flask with 0.1M HCl solution. Titre values of the replicate samples were recorded and percentage nitrogen calculated as shown in Equ 5. A blank sample was run at the same time as the sample is being analyzed [14].

$$\%\text{Nitrogen} = \left[\frac{(St - Sb)\text{x NA x } 100 \text{ x } 0.1 \text{ x } 0.014 \text{ x } 100}{\text{Sample weight x } 10}\right] \quad \text{.....Equ 5}$$

Where: S_t= Titre of sample; S_b= Titre of blank; NA = Normality of acid; N= Nitrogen; F= Factor (6.25); % Protein = % N x F.

Results and Discussion

Effects of varieties and harvesting stages on seed yield of soybean

There was significant variety x harvesting stage interaction (P≤0.05) for seed yield. Jenguma and Nanbgaar each at physiological maturity harvesting stage produced significantly the highest seed yield (Table 1). The least seed yield was produced by Nangbaar harvested two weeks after physiological maturity. Across harvesting stages, Jenguma variety produced significantly the highest seed yield as compared to Nangbaar and Anidaso which were similar in their seed yield. The finding of the present study is in agreement with Asafo-Adjei *et al.* (2005) who reported higher grain yields for Jenguma (1.7 – 2.8 tons/ha) than for both Nangbaar (1.5 – 2.5 tons/ha) and Anidaso (1.2 -1.8 tons/ha) [12].

Across varieties, harvesting at physiological maturity resulted in the highest seed yield, significantly different from the other harvesting stages (Table 1). These findings confirmed the report of Vasudevan *et al.* (2008) that harvesting of the seed crop at physiological maturity is better as seeds will be having maximum dry weight, higher viability and vigour, besides higher seed yield and yield attributing parameters [6]. Moreover, the research findings revealed that if soybean harvesting is delayed by one and two weeks after physiological maturity, seed yield loss of 49.4% and 63.2%, are likely to be encountered by producers. Boudreaux and Griffin (2008) posited that leaving soybean plants in the field past maturity exposes seed to adverse weather conditions that can reduce yield and quality [15].

Table 1: The effect of harvesting stages of soybean varieties on seed yield (g)

Harvesting Stages	**Soybean Varieties**			**Mean**
	Nangbaar	**Anidaso**	**Jenguma**	
Harvesting at physiological maturity	1231.70	904.00	1186.30	1107.33
Harvesting one week after physiological maturity	422.80	503.20	753.50	559.83
Harvesting two weeks after physiological maturity	290.50	349.50	583.20	407.73
Mean	648.33	585.57	841.00	

Tukey HSD (0.05): Variety = 102.28; Harvesting Stages = 102.28; Variety x Harvesting Stages = 244.32.

Effects of varieties and harvesting stages on shattering loss of soybean seed

The interaction effect of variety x harvesting stage was not significant in respect of percentage shattering loss of seeds. However, among the varieties, Nangbaar and Anidaso recorded significantly the highest percentage shattering losses of 19.44% and 16.92%, respectively. Jenguma on the contrary had the least shattering loss (14.86%) (Table 2). None of the varieties harvested at physiological maturity stage experienced shattering loss of seeds. This is in contrast with the same varieties harvested one and two weeks after physiological maturity which encountered significantly higher shattering losses.

The study also revealed that delaying harvesting by one and two weeks after physiological maturity resulted in 20 and 31.22% shattering loss, respectively, of the total seed weight. According to Asafo-Adjei *et al.* (2005), if soybean is left on the field after the pods are dry, the seeds may shatter, especially in the north where the dry harmattan winds can speed up the shattering process [12]. Harvesting too late may increase the risk of shattering and decrease the quality of seeds due to ageing [16-17].

Table 2: Percentage shattering loss of three soybean varieties

Soybean Varieties	Shattering loss (%)
Nangbaar	19.44
Anidaso	16.92
Jenguma	14.86
Mean	17.07
Tukey HSD (0.05)	3.89

Table 3: Effect of harvesting stages on percentage shattering loss of soybean seeds

Harvesting Stages	**Shattering loss (%)**
Harvesting at physiological maturity	0.00
Harvesting one week after physiological maturity	20.00
Harvesting two weeks after physiological maturity	31.22
Mean	17.07
Tukey HSD (0.05)	3.89

Effects of varieties and harvesting stages on germination of soybean seed

There was significant variety x harvesting stage interaction (P≤0.01) for germination capacity of the seeds (Table 4). Nangbaar and Anidaso each at physiological maturity harvesting stage recorded the highest germination percentage (85.25%). Nangbaar harvested two weeks after physiological maturity was as good as Jenguma harvested at physiological maturity. The least seed germination percentage (58.83%) was produced by Jenguma harvested two weeks after physiological maturity (Table 4). Harvesting at physiological maturity stage resulted in high germination percentage, significantly different from the other harvesting stages. Harvesting two weeks after physiological maturity registered the lowest germination percentage (Table 4). Current findings confirmed the report by Mahesha *et al.* (2001) that at physiological maturity, seed shall have maximum viability and vigour. Nangbaar variety had significantly the highest germination percentage (76.61%) as compared to Jenguma which obtained the least (63.42%) (Table 4) [18].

Table 4: The effect of harvesting stages on germination (%) of soybean seeds

Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	85.25	85.25	66.75	79.08
Harvesting one week after physiological maturity	77.25	68.00	64.67	69.97
Harvesting two weeks after physiological maturity	67.33	60.92	58.83	62.36
Mean	76.61	71.39	63.42	
Tukey HSD (0.01): Variety = 3.82; Harvesting Stages = 3.82; Variety x Harvesting Stages = 8.24.				

Effects of harvesting stages on vigour of soybean seed

There were no significant interactions for seed vigour. However, between varieties, Jenguma obtained the highest electrical conductivity value (37.87 µS $cm^{-1}g^{-1}$). Both Anidaso and Nangbaar recorded the lowest (35.20 µS $cm^{-1}g^{-1}$ and 35.56 µS $cm^{-1}g^{-1}$ respectively) though there were no significant differences between them (Table 5). Between the harvesting stages, varieties harvested two weeks after physiological maturity registered significantly the highest conductivity value (40.49 µS $cm^{-1}g^{-1}$) than the other harvesting stages (Table 6). Similarly, the electrical conductivity value for varieties harvested one week after physiological maturity was significantly higher (36.20 µS $cm^{-1}g^{-1}$) than those harvested at physiological maturity (31.93 µS $cm^{-1}g^{-1}$).

ISTA (2007) indicates that seed lots that have high electrolyte, that is, having high leachate conductivity, are considered as having low vigour, whilst those with low leakage (low conductivity) are considered high vigour seeds [13]. This implies that seeds harvested at physiological maturity were more vigorous and had good seed coat integrity than seeds harvested one and two weeks after physiological maturity. This explains why germinability was high in varieties harvested at physiological maturity than those harvested one and two weeks after physiological maturity. Further, among varieties, Jenguma recorded the highest conductivity value than both Nangbaar and Anidaso. These results also highlight the reason why germination percentage was low in Jenguma but high in Nangbaar and Anidaso.

Table 5: Seed Conductivity (Vigour) of three soybean varieties

Soybean Varieties	**Seed Conductivity (µS $cm^{-1}g^{-1}$)**
Nangbaar	35.56
Anidaso	35.20
Jenguma	37.87
Mean	36.21
Tukey HSD (0.01)	2.74

Table 6: Effect of harvesting stages on seed conductivity (Vigour) of soybean seeds

Harvesting Stages	**Seed Conductivity (µS $cm^{-1}g^{-1}$)**
Harvesting at physiological maturity	31.93
Harvesting one week after physiological maturity	36.21
Harvesting two weeks after physiological maturity	40.49
Mean	36.21
Tukey HSD (0.01)	2.74

Effects of varieties and harvesting stages on moisture content of soybean seed

There was significant variety x harvesting stage interaction (P≤0.01) for seed moisture content (Table 7). Anidaso variety harvested one and two week(s) after physiological maturity produced seeds with the lowest

(8.12%) moisture content. The highest seed moisture content was recorded by Nangbaar harvested one week after physiological maturity stage (8.62%).

Harvesting one week after physiological maturity stage registered significantly high percentage seed moisture content whereas those harvested two weeks after physiological maturity had the lowest (Table 7). Across harvesting stages, Anidaso had significantly the lowest seed moisture content of 8.17% while Nangbaar obtained the highest of 8.52%.

The results indicated that the seed moisture content ranged between 8.12 and 8.62 %. These figures were within the safe moisture limit for long storage and implied that the seeds were dried properly. Daun (1995) recommended that oilseeds storage for extended period is only possible if the seed moisture content is less than 10 % or preferably dried to 8 % [19].

Table 7: Interaction effects of varieties and harvesting stages on moisture content (%).

Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	8.49	8.28	8.38	8.38
Harvesting one week after physiological maturity	8.62	8.12	8.43	8.39
Harvesting two weeks after physiological maturity	8.44	8.12	8.36	8.31
Mean	8.52	8.17	8.39	
Tukey HSD (0.01): Variety = 0.08; Harvesting Stages = 0.08; Variety x Harvesting Stages = 0.17.				

Effects of varieties and harvesting stages on protein content of soybean seeds

No significant variety x harvesting stage interaction (P≤0.01) was observed for seed protein content. However, between varieties, Anidaso produced significantly the highest protein content (29.43%) than the other varieties. Jenguma and Nangbaar obtained the lowest protein content 28.78% and 28.91%, respectively (Table 8). There was no significant difference between the harvesting stages. Adu-Dapaah *et al.* (2005) found the average protein content of Nangbaar at physiological maturity to be 43.00±0.18% and 46.38±0.08% for Anidaso. This implies that the average percentage protein content obtained from this study was low as compared to the findings of Adu-Dapaah *et al.* (2005) [20].

Table 8: Protein content of three soybean varieties

Soybean Varieties	Protein Content
Nangbaar	28.91
Anidaso	29.43
Jenguma	28.78
Mean	29.04
Tukey HSD (0.05)	0.13

Effects of varieties and harvesting stages on oil content of soybean seed

Significant variety x harvesting stage interaction was observed (P≤0.01) for seed oil content (Table 9). Anidaso harvested at physiological maturity stage produced significantly the highest seed oil content (18.61%) whereas Nangbaar harvested one week after physiological maturity recorded the least oil content (18.17%). Harvesting at physiological maturity stage resulted in high seed oil content (18.39%) whilst harvesting two weeks after physiological maturity resulted in the least oil content (18.28%). Anidaso produced the maximum oil content (18.53%). Nangbaar on the other hand obtained the minimum oil content (18.21%) (Table 9).

Adu-Dapaah *et al.* (2005) recorded an average fat content of 16.77±0.23% for Nangbaar and 16.45±0.07% for Anidaso at physiological maturity. The implication was that the fat content obtained in this study was comparatively high to that of Adu-Dapaah *et al.* (2005). However, it confirmed the findings of Sauvant *et al.* (2004) that at maturity, soybean contains 18% oil [20-21].

Table 9: The effect of harvesting stages and variety on percent seed oil content (%) of soybean

Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	18.22	18.61	18.33	18.39
Harvesting one week after physiological maturity	18.17	18.59	18.28	18.35
Harvesting two weeks after physiological maturity	18.24	18.39	18.21	18.28
Mean	18.21	18.53	18.27	
Tukey HSD (0.05):Variety = 0.05 ; Harvesting Stages = 0.05; Variety x Harvesting Stages = 0.11.				

Conclusion

The results indicate that Jenguma had the highest seed yield while Anidaso recorded the least. Soybean varieties harvested at physiological maturity stage obtained the highest seed yield and no shattering loss as compared to the other harvesting stages. Seed yield of soybean decreased with increasing delay in harvesting. Soybean varieties harvested at physiological maturity registered a high germination percentage and vigour than those harvested one and two weeks after physiological maturity. Soybean varieties harvested at physiological maturity stage produced high seed oil content whereas harvesting two weeks after physiological maturity resulted in the least oil content. Anidaso registered significantly the highest protein content whilst Jenguma obtained the lowest.

References

[1]. Marcos-Filho, J., Chamma, H. M. C. P., Casagrande, J.R. R. and Marcos, E.A. (1994). Effect of harvesting time on seed physiological quality, chemical composition and storability of soybeans. Sci. agric., Piracicaba, 51(2); 298-304.

[2]. Delouche, J.C., Matthens, R.K., Dougherty, G.M. and Boyd, A.H. (1973). Storage of seed in sub-tropical and tropical regions. Seed Sci. Technol. 1: 633-692.

[3]. Hans, K., Fjell, L.D. and Kilgore, G.L. (1997). Seed Bed Preparation and Planting Practices: Soybean Production Handbook. Kansas State University, Kansas, pp: 8. Quoted from: Evaluation of Screening Methods for Improved Storability of Soybean Seed. Addai, I.K.and O. Safo- Kantanka (2006). International Journal of Botany, 2: 152-155.

[4]. Kumar, V., S. D. Shahidhan, M. B. Kurdikeri, A. S. Channaveeraswami and R. M. Hosmani. (2002). Influence of harvesting stages on seed yield and quality in paprika (Capsicum annuum L.). Seed Res. 30(1): 99-103.

[5]. SARI (2012). Soybean: A production guide for northern Ghana. Alliance for a Green Revolution in Africa Soil Health Project, 2009 SHP 005. Pp. 4-7.

[6]. Vasudevan, S. N., Sudarshan, J. S. Kurdikeri, M. B. Dharmatti, P. R. (2008). Influence of harvesting stages on Seed Yield and Quality in Fenugreek. Karnataka J. Agric. Sci., 21 (1): (122-124).

[7]. Kandel, H. (Ed.). (2010). Soybean Production. North Dakota State University, Fargo, Norht Dakota. Pp. 128 – 142.

[8]. Khatun, A., Kabir, G. and Bhuiyan, M. A. H. (2009). Effect of harvesting stages on the seed quality of Lentil (Lens culinaris L.) during storage. Bangladesh J. Agric. Res. 34(4): 565-576.

[9]. Narayan, R., Chauhan, G. S. and Verma, N. S. (1988a). Changes in the quality of soybean during storage. Part 1- Effect of storage on some physic-chemical properties of soybean. Food Chemistry, Vol. 27, No.1, pp. 12-23.

[10]. Narayan, R., Chauhan, G. S. and Verma, N. S. (1988b). Changes in the quality of soybean during storage. Part 2- Effect of soybean storage on the sensory qualities of the products made there from. Food Chemistry, Vol. 30, No.3, pp. 181-190.

[11]. Balesevic-Tubic, S., Tatic, M., Hrustic, M., Miladinovic, J., Maksimovic, L., (2007). The influence of aging process on germination and seedling growth of sunflower seed. In: Proceedings of the First Joint PSU-UNS International Conference on BioScience: Food, Agriculture, and the Environment, Thailand: 198-202.

[12]. Asafo-Adjei, B., Ansah I.O.O., Asuboah, R.A., Dapaah, H., Harruna M., and Oti-Boateng, C. (2005). CSIR (CRI and SARI) and MOFA. Soybean Production Guide. Food Crops Development Project, Ghana. Pp 1-39.

[13]. ISTA (2007). International Rules for Seed Testing. International Seed Testing Association, Bassersdorf, Switzerland.

[14]. AOAC International. (2007). Official methods of analysis, 18th edn. 2005; Current through revision 2, 2007 (Online). AOAC International, Gaithersburg, MD.

[15]. Boudreaux, J. M. and Griffin, J. L. (2008). Harvest aids in indeterminate and determinate soybeans—application timing and value. Louis. Agri 51:26–27. Cited from: Application Timing of Harvest Aid Herbicides Affects Soybean Harvest and Yield. Boudreaux, J. M. and J. L. Griffin (2011). Weed Technology, 25(1):38-43.

[16]. Ellis, R.H and Pieta-Filho, C. (1992). Seed development and cereal seed longevity, Seed. Sci. Res., 3: 247-257.

[17]. Wang, Y., Mu, C., Hou, Y. and Li, X. (2008). Optimum harvest time of Vicia cracca in relation to high seed quality during pod development. Crop Sci., 48: 709-715.

[18]. Mahesha, C. R., Channaveeraswami, A. S., Kurdikeri, M. B., Shekhargouda, M. and Merwade, M. N. (2001). Seed maturation studies in sunflower genotypes. Seed Res. 29(1): 95-97.
[19]. Daun, J. K. (1995). Seed Analysis. In: Brassica Oilseeds. Production and Utilization. (Eds) D.S. Kimber and McGregor, D. I. CAB international. Pp 245.
[20]. Adu-Dapaah, H.K., Asibuo J.Y., Asafo-Adjei. B., Dashiel, K., Amoah, S., Asafu-Adjei, J.N. and Addo, J.K. (2005). Breeding Methodology, Botanical and Agronomic Characteristics of four Groundnut, Two Cowpea and two Soybean Genotypes Proposed for Release. Pp. 42-60.
[21]. Sauvant, D., Perez, J. M., and Tran, G. (Ed.). (2004). Tables of composition and nutritional value of feed materials, *INRA*, France. Quoted from: Fatty Acid Composition of Various Soybean Products. Ivanov D. S., J. D. Lević, and S. A. Sredanović. Journal of the Institute for Food Technology in Novi Sad, *Bulevar cara Lazara 1, Serbia.*