Kasetsart J. (Nat. Sci.) 44 : 167 - 173 (2010)

Effects of Seeding Rates and Harvesting Period on Yield, Oil and Protein Content and Aflatoxin Incidence in Sesame Seed (*Sesamum indicum* L.)

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ABSTRACT

A field experiment was conducted at the National Corn and Sorghum Research Center, Pak Chong, Nakhon Ratchasima during the 2008 rainy season to investigate the effects of seeding rates and harvesting period on sesame yield, oil and protein content and the incidence of aflatoxin. A split-plot in randomized complete block (RCB) design was used, with seeding rates (4, 6, 8 and 10 kg ha^{-1}) allocated to the main plots and harvesting periods (52, 56 and 60 days after flowering, DAF) assigned to sub-plots with four replications. There were interactions between seeding rates and harvesting periods. Seed yield was significantly affected by both seeding rates and harvesting period. Harvesting at 52 DAF produced higher seed yields at each seeding rate. The mean oil and protein content was 37.46% and 26.36%, respectively. Aflatoxin contamination in seeds was 7.58 ppb, which was less than the 20 ppb maximum limit.

Key words: seeding rates, harvesting periods, seed yield, oil and protein contents, aflatoxin

INTRODUCTION

Sesame is cultivated worldwide, mostly in the tropics and sub-tropics. In Myanmar, it is the major source of edible oil for local consumption, occupies the largest area (53% of the total oil-seed crop) and is mostly grown under rain-fed conditions. Due to the vagaries of the weather, over 40% of the total crop is damaged, leading to additional yield losses, due to management constraints resulting from a lack of good quality seed for the following season. Broadcasting seed is still common and is practiced at various seed rates, but lower yields are obtained, due to poor management practices. Crop management is essential for successful production, in addition to quality seed, optimum seeding rate, proper fertilization, irrigation and weed control, sowing method, optimum sowing time, plant density and optimum harvesting time. Shattering in sesame is also a yield-limiting factor. Seed loss may reduce yield by 60% (Boyle and Oemcke, 1995). Because sesame has an indeterminate growth habit, timing of harvest is important. Sesame seeds typically contain greater oil content than many other oilseeds, ranging from 37 to 63%.

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Received date : 07/10/09 Accepted date : 18/11/09

Sesame seeds have been reported to contain about 51% oil, 17-19% protein and 16-18% carbohydrate (Yermanos *et al*., 1972). The oil content and composition is markedly influenced by genetic, climatic and agronomic factors and varies considerably within varieties (Yoshida *et al*., 2007). Aflatoxins, produced by *Aspergillus flavus*, *A. parasiticus, A. nomius, A. tamarii* and *A. bombycis* (Kurtzman *et al*., 1987; Goto *et al*., 1997; Peterson *et al*., 2001), are acutely and chronically toxic to both humans and animals and designated as B_1, B_2, G_1, and G_2. Aflatoxin contamination occurs mainly during cultivation, crop development and pod maturation, particularly where there has been water stress, end-of-cycle drought or insect damage to pods during harvest and storage. Research work on seeding rates and harvesting periods in sesame is limited, especially in Myanmar. Therefore, the present study was undertaken to determine the optimum seeding rate and harvesting time to obtain a high yield and good quality of sesame seed with no or low incidence of aflatoxin contamination.

MATERIALS AND METHODS

The field experiment was carried out at the National Corn and Sorghum Research Center (Suwan Farm), Pak Chong, Nakhon Ratchasima province during the 2008 rainy season (June-September). A split plot in RCB design was used with four replications. The main plots contained four seeding rates (4, 6, 8 and 10 kg ha^{-1}) of black sesame KU-18 variety and the sub-plots were established based on three harvesting periods (52, 56 and 60 days after flowering, DAF). The plot size was 4m × 5m and consisted of eight rows. In June 2008, sesame seed was drilled by hand in rows 50 cm apart. Compound fertilizer (15-15-15) was applied at the rate of 155 kg ha^{-1} one week after planting, hand weeding was carried out twice and there was no thinning. Sprinkler irrigation and chemicals were applied whenever necessary during the growth period of the crop. All other normal agronomic practices were applied uniformly across all treatments.

During the growing period, it was observed that different seeding rates resulted in different plant populations. Drilling the seed at the rate of 4, 6, 8 and 10 kg ha^{-1} resulted in plant densities at the seedling stage of 658,083, 962,667, 1,136,420 and 1,468,830 plants ha^{-1}, respectively. However, for the same drilling rates, at harvest time, final plant populations were 493,583, 585,917, 671,750 and 712,083 plants ha^{-1}, respectively. The reduction in plant populations was due to interplant competition for factors influencing growth. Sesame plant losses of 25, 39, 41 and 52%, respectively, were noted from the seeding rates of 4, 6, 8 and 10 kg ha^{-1}. Similar loss rates have been reported elsewhere (Mazzani, 1966; Weiss, 1971).

Ten plants from each plot were randomly selected at harvest and measured for plant height, number of nodes per plant, average number of capsules per plant, average number of seeds per capsule and the weight of 1,000 seeds (1000-seed weight). At maturity, the four rows in the center of each sub-plot, having an area of 6 m^2, were harvested for their seed. After drying and cleaning, seeds were stored at 13°C and 70% RH until analyzed for % oil content and protein content, using the Soxtex and the Kjeltex systems, respectively. Aflatoxin contamination was determined by ELISA (enzyme linked immuno sorbent assay). Chemical analysis and aflatoxin determination were carried out at the Post-Harvest and Products Processing Research and Development Office, Department of Agriculture, Chatuchak, Bangkok. The International Rice Research Institute statistical method was used to compute the analysis of variance (ANOVA) and differences between treatment means were calculated using Fisher's least significant difference (LSD) method.

RESULTS AND DISCUSSION

Interaction effects of seeding rates and harvesting periods on plant height, height to 1st capsule, number of nodes and capsules per plant

There were interactions between seeding rates and harvesting periods for all parameters measured, except for 1000-seed weight (Tables 2 and 3). No significant differences in plant height among harvesting periods at seeding rates of 4, 6 and 8 kg ha^{-1} were observed, whereas harvesting at 56 DAF under the 10 kg ha^{-1} seeding rate produced shorter plants than the other rates, which consequently, tended to reduce the numbers of nodes and capsules per plant (Table 2). For each seeding rate, a delay in the time of harvest tended to increase the plant height when harvesting. Harvesting at 56 DAF of 6 and 8 kg ha^{-1} yielded the highest plants. A delay in harvesting allowed the sesame plants to grow taller because of the indeterminate growth habit of sesame. The seeding

Table 1 Meteorological data in the experimental area during the sesame-growing period in 2008.

Month	Average temperature (°C)		Relative humidity (%)	Rainfall(mm)
	Min.	Max.		
June	23.3	31.0	77	50.0
July	23.7	31.3	72	43.7
August	22.9	30.6	77	151.8
September	22.4	29.4	83	363.7
October	22.1	30.2	83	229.5
November	20.1	28.0	73	9.4

Table 2 Interaction effects of seeding rates (a) and harvesting periods (b) on plant height at harvest, height to 1st capsule, and the numbers of nodes and capsules per sesame plant.

Interaction (a × b)	Plant height at harvest (cm)	Height to 1st capsule (cm)	Nodes per plant	Capsules per plant
4 × 52	121ab	47ab	20ab	32 b
× 56	120ab	46ab	21ab	35ab
× 60	123 a	46ab	23 a	40 a
6 × 52	118ab	45ab	19 b	27bc
× 56	125 a	40 b	21ab	35ab
× 60	122 a	49 a	22ab	38ab
8 × 52	122 a	50 a	18 b	27bc
× 56	126 a	47ab	21ab	34ab
× 60	118ab	51 a	19 b	30bc
10 × 52	117ab	46ab	20ab	27bc
× 56	112 b	46ab	16 b	24 c
× 60	119ab	53 a	18 b	28bc
CV (a) (%)	20.12	14.84	13.44	16.12
CV (b) (%)	5.56	12.55	13.41	16.98

Note:
abc = within each column, means followed by the same letter or letters are not significantly different at P<0.05 as determined by Fisher's LSD.

rate of 6 kg ha^{-1} with harvesting at 56 DAF had a shorter height to the 1st capsule compared with the other rates. Although significant differences in nodes per plant among harvest periods at each seeding rate were not found, a delay in harvesting increased the number of nodes per plant, except for the 10 kg ha^{-1} seeding rate. In general, lower seeding rates had higher numbers of nodes per plant. The number of capsules per plant decreased with higher seeding rates, whereas differences in the number of capsules per plant among harvest periods at each seeding rate were not observed (Table 2). A delay in harvesting tended to increase the number of capsules per plant at each seeding rate, whereas harvesting at 56 DAF of the 10 kg ha^{-1} seeding rate produced the lowest numbers of nodes and capsules per plant; this may have been due to these conditions also producing the lowest height of sesame plants in the trial. The maximum numbers of nodes and capsules per plant resulted from a planting rate of 4 kg ha^{-1}, with harvesting at 60 DAF followed by 6 kg ha^{-1} with harvesting at 60 DAF.

Interaction effects of seeding rates and harvesting periods on yield, capsule length, number of seeds per capsule and 1000-seed weight

Harvesting at 52 DAF gave a greater yield than at other harvest times for each seeding rate (Table 3). For each seeding rate, a delay in harvesting reduced seed yield, tended to shorten capsule length and reduced the number of seeds per capsule. The seeding rate of 10 kg ha^{-1} harvested at 60 DAF gave the lowest seed yield. Increased yield losses might have been due to the indeterminate growing characteristics, which prevented uniform maturation of the seed. Harvesting at 56 DAF generally produced greater capsule length, particularly for seeding rates of 4, 6 and 8 kg ha^{-1}, whereas there were no significant differences in capsule length among harvest periods at the 10 kg ha^{-1} seeding rate (Table 3). The seeding rate of 10 kg ha^{-1} with harvesting at 56 DAF produced fewer seeds per capsule than the other rates, due to these harvesting conditions producing the lowest values in yield parameters,

Table 3 Interaction effects of seeding rates (a) and harvesting periods (b) on seed yield, capsule length, number of seeds per capsule and 1000-seed weight of sesame.

Interaction (a × b)	Seed yield (kg ha^{-1})	Capsule length (cm)	Seeds per capsule	1000-seed weight (g)
4 × 52	1267 a	3.72 b	74ab	3.38
× 56	775 bc	4.04ab	71ab	3.47
× 60	855 bc	3.88ab	77 a	3.24
6 × 52	1211 a	3.76 b	75ab	3.24
× 56	924 b	4.09 a	73ab	3.35
× 60	585 c	3.74 b	73ab	3.25
8 × 52	1059 ab	3.75 b	79 a	3.37
× 56	919 b	3.89ab	72ab	3.24
× 60	731 bc	3.68 b	72ab	3.40
10 × 52	1118 ab	3.72 b	76ab	3.35
× 56	695 c	3.79 b	65 b	3.30
× 60	544 c	3.68 b	74ab	3.11
CV (a) (%)	16.44	5.43	8.53	7.28
CV (b) (%)	16.44	5.28	10.11	7.62

abc = within each column, means followed by the same letter or letters are not significantly different at P<0.05 as determined by Fisher's LSD.

such as plant height and the number of nodes and capsules per plant. No significant differences in the 1000-seed weight among seeding rates and harvesting periods were observed.

Aflatoxin contamination

Even though the data were not analyzed statistically, there were noticeable trends in the results. The levels of aflatoxin B_1 in sesame seed ranged from 4.58 to 9.44 ppb with a mean value of 7.58 ppb (Table 4). The maximum allowable limit in food for human consumption set by the Food and Drug Administration in the USA (USFDA) is 20 ppb (Guo *et al.*, 2008). Internationally, depending upon the country, levels are typically within a range of 4 to 15 ppb. Although the mean level of aflatoxin B_1 (7.58 ppb) was less than the USFDA maximum allowable limit of 20 ppb , three environmental factors (Table 1), namely the amount of rainfall, temperature and relative humidity (RH), affected aflatoxin production in the field (Montani *et al.*, 1988; Karunaratne *et al.*, 1990; Ellis *et al.*, 1991). Average air and soil temperatures of 25-35∞C and RH values above 70% were favorable for aflatoxin contamination. Denizel *et al.* (1976) reported that 82% RH was the minimum value required for *A. flavus* spore germination and aflatoxin production in Turkish pistachio nuts. Heavy rain during crop growth in a rain-fed crop is conducive to fungal diseases. These factors may have been responsible for the incidence of aflatoxin contamination in all the samples. The most appropriate aflatoxin-minimizing strategies are the use of varieties with less risk of contamination, improved postharvest crop processing and storage methods, and sorting out of contaminated produce.

Oil and protein contents

The range of oil and protein on a moisture-free basis in sesame ranged from 32.80 to 42.80% and 25.60 to 27.00%, respectively. The average oil content was 37.46% and the protein content was 26.36%. At any seeding rate, delayed harvesting resulted in lower values for aflatoxin B_1 and oil content, but no changes in the protein content (Table 4). Kinman and Stark (1954) reported that the chemical composition of seeds

Table 4 Effects of seeding rates (kg ha^{-1}) and harvesting periods (days after flowering, DAF) on aflatoxin contamination, and the oil and protein content of sesame.

Seeding rates (kg ha^{-1})	Harvesting periods (DAF)	Aflatoxin (ppb)	Oil content (%)	Protein content (%)
4	52	9.44[1]	42.10[1]	26.00[1]
	56	6.47	38.60	26.60
	60	8.07	33.00	26.20
6	52	7.29	35.80	25.80
	56	9.10	40.70	26.70
	60	4.58	34.20	26.10
8	52	8.63	32.80	25.60
	56	9.05	42.80	26.30
	60	5.78	36.80	26.30
10	52	7.47	41.70	26.90
	56	7.33	34.40	26.80
	60	7.71	36.60	27.00
Mean		7.58	37.46	26.36

Note:
[1] no statistical analysis was possible,as only a single measurement was taken (bulked samples).

was affected not only by genotype, but also by agro-climatic conditions. The genotype-environment interaction is the key factor in the assessment of crop-variety performance in terms of quantity and quality of produce.

CONCLUSION

The highest seed yield was obtained from the 4 kg ha^{-1} seeding rate with early harvesting at 52 DAF. Harvesting at 52 DAF produced higher seed yields than any other harvest periods and seeding rates. Therefore, planting sesame at the 4 kg ha^{-1} seeding rate with harvesting at 52 DAF was the most suitable regime for row planting in the rainy season. Plant variety, climatic conditions, soil fertility and sowing time strongly influenced the time of harvest. Delaying harvesting also tended to reduce the oil content and reduced the incidence of aflatoxin contamination. However, seed protein content remained constant. Aflatoxins are considered a potential hazard to human and animal health, due to their toxicity and carcinogenicity. Although the aflatoxin concentration in seeds was not at a toxic level, they were considered unfit for human consumption and trade, and thus the concentration level may reduce the seed quality for consumption.

ACKNOWLEDGEMENTS

The authors would like to thank the Ministry of Agriculture and Irrigation, Myanmar, and FAO for granting a fellowship to the first author, through the UTF/MYA/006/MYA Oil Crops Development Project and for financial support of this research. Special thanks are due to the staff of the National Corn and Sorghum Research Center for field assistance. The authors thank reviewers for their valuable suggestions and help.

LITERATURE CITED

Boyle, G.J. and D.J. Oemcke. 1995. Investigation of methods to reduce preharvest seed losses in sesame, pp. 169-172. *In* M.R. Bennett and I.M. Wood (eds.). **Proc. the First Australian Sesame Workshop,** Darwin and Katherine, Australia.

Denizel, T., E.J. Rolfe and B. Jarvis. 1976. Moisture equilibrium relative humidity relationships in pistachio nuts with particular regard to control of aflatoxin formation. **J. Sci. Food Agric.** 27: 1027-1034.

Ellis, W.O., J.P. Smith, B.K. Simpson and J.H. Oldham. 1991. Aflatoxins in food: occurrence, biosynthesis, effects on organisms, detection, and methods of control. **Crit. Rev. Food Sci. Nut.** 30: 403-439.

Goto, T., Y. Ito, S.W. Peterson and D.T. Wicklow. 1997. Mycotoxin producing ability of *Aspergillus tamarii*. **Mycotoxins** 44: 17-20.

Guo, B., Z.Y. Chen, R.D. Lee and B.T. Scully. 2008. Drought stress and preharvest aflatoxin contamination in agricultural commodity: genetics, genomics and proteomics. **J. Integr. Plant Biol.** 50(10): 1281-1291.

Karunaratne, A., E. Wezenberg and L.B. Bullerman. 1990. Inhibition of mold growth and aflatoxin production by *Lactobacillus spp*. **J. Food Prot.** 53(3): 230-236.

Kinman, M.L. and S.M. Stark. 1954. Yield and chemical composition of sesame, *Sesamum indicum* L., as affected by variety and location grown. **J. Am. Oil Chem. Soc.** 31(3): 104-108.

Kurtzman, C.P., B.W. Horn and C.W. Hesseltine. 1987. *Aspergillus nomius*, a new aflatoxin-producing species related to *Aspergillus flavus* and *Aspergillus tamarii*. **Antonie van Leeuwenhoek** 53: 147-158.

Mazzani, B. 1966. The cultivation of sesame. Agronomia. Caracas. pp. 9-18. *In* H. Veenman and B.V. Zonen (eds.). **Major Problems of**

Growing Sesame (*Sesamum indicum* L.) in Nigeria. Wageningen University, Netherlands.

Montani, M.L., G. Vaamonde, S.L. Resnik and P. Buera. 1988. Water activity influence on aflatoxin accumulation in corn. **Int. J. Food Microbiol.** 6: 349-353.

Peterson, S.W., Y. Ito., B.W. Horn and T. Goto. 2001. *Aspergillus bombycis*, a new aflatoxigenic species and genetic variation in its sibling species, *A. nomius*. **Mycologia.** 93(4): 689-703.

Weiss, E.A. 1971. **Castor, Sesame and Safflower.** Leonard Hill Books. London.

Yermanos, D.M., S. Hemstreet, W. Saleed and C.K. Huszar. 1972. Oil content and composition of the seed in the world collection of sesame introductions. **J. Am. Oil Chem. Soc.** 49(1): 20-23.

Yoshida, H., M. Tanaka, Y. Tomiyama and Y. Mizushina. 2007. Regional distribution in the fatty acids of triacylglycerols and phospholipids of sesame seeds (*Sesamum indicum*). **J. Food Lipids.** 14: 189-201.