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Plant Density Influence on Yield and Nutritional Quality of Soybean Seed

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Abstract: Plant density is an important factor affecting soybean seed yield and but information regarding plant density effects on seed quality is highly scarce. The present study examines the relationship of seed yield and quality of two soybean varieties viz., PB-1 and G-2 with plant densities. The experiments were conducted in three consecutive seasons viz., Rabi 2004-05, Kharif 2005 and Rabi 2005-06 at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh, Bangladesh. Six plant densities viz., 20, 40, 60, 80, 100 and 120 plants m^{-2} were established using an equidistant planting pattern having spacings of 22.4×22.4 cm, 15.8×15.8 cm, 12.9×12.9 cm, 10.0×10.0 cm and 9.1×9.1 cm, respectively. A split-plot design was used having variety as main plot and density as sub-plot with three replicates. The results revealed that soybean seed yield increased with increase of plant density and the highest yield was obtained at 80 to 100 plants m^{-2} depending on variety and season. The further increase in plant density reduced the seed yield. The seed yield, seed protein and mineral contents such as phosphorus, calcium, potassium, sulphur and zinc showed a quadratic relation with plant density. Seed protein content decreased with increase in plant density up to 80 or 100 plants m^{-2} and then increased with further increase in plant density while reverse occurred for seed yield and different minerals. The results also showed that seed protein content was inversely related with seed yield and mineral contents in seed.

Key words: Equidistant planting pattern, *Glycine max*, variety, mineral contents, protein content

INTRODUCTION

Soybean (*Glycine max* L. Merr.) is regarded as the "miracle golden bean" and "nutrition of nugget" for its high protein and mineral contents. Soybean seed contains 42-45% protein and very high amount of P, K, Ca, Zn and other minerals. Plant density influences seed yield by modulating crop environment. Manipulation of plant density affects plant structural characteristics and helps improve disease avoidance, lodging resistance, adaptation to mechanical harvesting and seed yield in soybean (Khan *et al*., 2003; Rigsby and Board, 2003). Shafshak *et al*. (1997) also reported that increased plant density increased plant height and seed yield in soybean. In the USA, the optimum plant populations vary from 30 to 50 plants m^{-2} (Grichar, 2007). In Iran, the highest yield was found with a plant density of 60 plants m^{-2} (Daroish *et al*., 2005). In India, the highest seed yield was also reported with 60 plants m^{-2} (Singh, 2010). On the other hand, in Turkey, the highest soybean yield was found at a very low plant density of 12.8 plants m^{-2} (Zaimoglu *et al*., 2004) and 28.5 plants m^{-2} (Mehmet, 2008). Rahman *et al*. (2004) found that the optimum plant density for soybean in Canterbury, New Zealand was 40 plants m^{-2}. In South Korea, Kang *et al*. (1998) showed that increased plant density from 33 to 53 plants m^{-2} increased the yield of soybean from 186 to 229 g m^{-2} while Cho and Kim (2010) recorded the highest yield with 66 plants m^{-2}. In Bangladesh, soybean is sown at 30 and 40 cm rows respectively in rabi (winter) and kharif (summer) seasons with about 5 cm plant to plant distance to establish plant density of 60 and 50 plants m^{-2}, respectively (BARI, 2005). In contrary to the general practice, Rahman and Hanif (2006) found the highest seed yield in rabi season with 20×5 cm spacing (plant density of 100 plants m^{-2}) in Bangladesh and the result indicated that soybean would require higher density than that being practiced. Holshouser and Jones (2003) reported that short duration soybean required higher plant density than the long duration crops for maximum yield. Thus it appears that optimum plant density of soybean depends on variety, geographical location, season and agronomic management practices.

Qualities of seed are acquired in a sequential and cumulative manner during seed development (Miles *et al*., 1988) and are influenced by the environmental condition under which it is grown (Yang and Fan, 1996; McDonald, 1999). Nutritional qualities such as protein, oil and mineral

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content of soybean seed depend on field production environment (Muhammad *et al*., 2009). Prasad *et al*. (1993) found that seed protein content decreased significantly with the increase in plant density from 17 to 33 plants m^{-2}. Similar results were reported by Jadhav *et al.* (1994) for densities of 22, 33 and 44 plants m^{-2}. On the other hand, El-Din *et al*. (1997) reported that soybean seed protein content increased with increase in plant density from 39 to 117 plants m^{-2}. Rahman *et al*. (2005a) found that the seed protein content in soybean decreased with increase in plant density up to 27.8 plants m^{-2} and then again increased with increase in plant density up to 71.6 plants m^{-2}. The accumulation of protein in seed is influenced by the field environment (Jian and Xinmin, 1992) and the seed protein content in soybean is inversely related with oil content (Yin and Vyn, 2005).

Soybean seed is very rich in different minerals but the research reports regarding the effect of plant densities on the mineral contents of soybean seed is scarce. Different kinds of food products are being produced from soybean seed for human consumption. Soybean seed is the raw material in many food and feed industries and therefore, high quality food and feed production depends on the quality of soybean seed being used in the industry. However, the information on the response of seed yield and quality of soybean to plant density is highly scarce. The present study was therefore, undertaken with a view to understanding the relationships of yield and nutritional quality of soybean seed with plant density for optimizing plant density to produce high quality seed for the food and feed industries.

MATERIALS AND METHODS

Site and soil: Field experiments were conducted at the Agronomy field laboratory (24°75' N, 90°50' E, Altitude 18 m), Bangladesh Agricultural University (BAU), Mymensingh during Rabi (dry and cool) 2004-05 and 2005-06 and kharif II (rainy and warm) 2005 seasons. The experimental area belongs to the Sonatola Soil Series under the Old Brahmaputra Floodplain Agro-ecological Zone (AEZ 9) with Non-calcareous Dark Grey Floodplain soil (UNDP/FAO, 1988). The soil was loam in texture having pH 6.84. The soil contained low organic matter (1.50%), total nitrogen (0.073%), phosphorus (12.0 ppm), sulphur (9.5 ppm), zinc (0.47 ppm) and medium amount of potassium (0.18%). The soil test result also showed that the amount of P, K, S and Zn were relatively higher in Kharif-II season than those in Rabi seasons while the amount of total nitrogen was higher in Rabi season than in Kharif-II season.

Treatment and design: Two soybean varieties viz., Bangladesh soybean-4 (G-2) and Shohag (PB-1) and six planting densities viz., 20, 40, 60, 80, 100 and 120 plants m^{-2} were included in the trial with a split plot design having variety been assigned into main plot and plant density into the subplots with three replications. The trial was conducted during three consecutive seasons such as rabi 2004-05, kharif 2005 and rabi 2005-06 growing seasons in the same plot with same trial design. Unit plot size was 4.4×3.0 m. Seed was sown after inoculation with Rhizobium inoculum on 6 January, 28 July and 3 December 2005 respectively for rabi 2004-05, kharif 2005 and rabi 2005-06 growing seasons. An equidistant square planting pattern having spacing 22.4×22.4 cm; 15.8×15.8 cm; 12.9×12.9 cm; 11.2×11.2 cm; 10×10 cm and 9.1×9.1 cm, respectively were used to create target plant densities of 20, 40, 60, 80, 100 and 120 plants m^{-2} as per experimental specification.

Husbandry: The experimental fields were opened on 26 December 2004 for Rabi 2004-05 season, on 20 July 2005 for Kharif-II 2005 season and 25 November 2005 for Rabi 2005-06 season. In both the Rabi seasons, a tractor drawn disc plough followed by harrowing with a power tiller were used to prepare a good seed bed while in Kharif-II season land preparation was done with a power tiller. Each unit plot was uniformly fertilized during final land preparation at 23-69-60-16-1 kg ha^{-1} N-P_2O_5-K_2O-S-Zn through urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate (BARI, 2005). Sowing was done on 6 January, 28 July and 3 December 2005, respectively for rabi 2004-05, kharif 2005 and rabi 2005-06 growing seasons. Three seeds were sown per hill at 2-3 cm depth. Prior to sowing seed was inoculated with Rhizobium inoculums collected from Bangladesh Institute of Nuclear Agriculture (BINA). Different intercultural operations such as weeding, thinning, gap filling and irrigation were done as and when needed. For example, weeding was done at 20 and 40 DAS in Rabi 2004-05, 20 and 30 DAS in Kharif-II 2005 and 21, 34 and 50 DAS in Rabi 2005-06 seasons followed by thinning to maintain a single seedling at each hill as per experimental specification. Gap filling was done at 42 DAS in Rabi 2004-05 and 35 DAS in Rabi 2005-06 seasons with the additional seedlings of same age raised in a corner of the experimental field and the irrigation was applied at the same day. In Kharif-II 2005 season, gap filling was done twice, first at 30 DAS and second at 37 DAS. In Rabi 2005-06 season, second irrigation was given at 65 DAS because the soil moisture deficit of a plot reached about 50% of the field capacity. The crop was infested by hairy caterpillar in all the three seasons. The rate of infestation was higher in Kharif-II season than Rabi seasons. The hairy caterpillar was successfully controlled with the application of Dimethion 40 EC at 1.5 Lha^{-1} at 65 DAS in Rabi 2004-05, 28, 44 and 56 DAS in Kharif-II 2005 and 61 DAS in Rabi 2005-06 seasons. There was no disease infection in the crop field.

Harvesting and processing: The crop was harvested at full maturity from the central 6.36 m^2 area (2.52×2.52 m) of each plot. In Rabi 2004-05, both the varieties were harvested on 20 April 2005, in Kharif-II 2005, variety G-2 and PB-1 were harvested on 27 October and 14 November 2005, respectively while in Rabi 2005-06, harvesting was done on 1 and 9 April 2006 respectively for variety G-2 and PB-1. After threshing, cleaning and drying the weight of seed of each plot was recorded at dry weight basis and seeds were kept in air tight polythene bags at 8% seed moisture content in the laboratory until further use.

Analysis of seed protein and mineral contents: The analysis of N, P, K, Ca, S and Zn content in soybean seed was done at the Central Laboratory, BAU, Mymensingh, Bangladesh. Seed samples were oven dried at 65°C for 48 h, then were finely grounded using a Wiley Mill and homogenous powder was obtained for analysis purpose after passing through a 60-mesh sieve. The total N in the seed was determined by Semi-micro Kjeldahl method (Bremner and Mulvaney, 1982) and P was determined by spectrophotometer (Olsen and Sommers, 1982). K was determined by flame photometry while Ca Zn and S were estimated by an Atomic Absorption Spectrophotometer (AAS). The protein content of seed was calculated as:

$$\text{Protein (\%)} = \text{Total N} \times 6.25$$

Statistical analysis: The experimental data were analyzed using two way-Analysis of Variance (ANOVA) techniques and mean differences were adjudged by Duncan's Multiple Range Test with the help of a computer package programme MASTAT-C. The correlation and regression analyses were done using statistical package program MINITAB.

RESULTS

Seed yield: Seed yield $plant^{-1}$ was affected significantly by plant density. The result showed that seed yield $plant^{-1}$ reduced significantly due to increase in plant density in all the three seasons. The highest seed yield $plant^{-1}$ was found with the lowest plant density in all the cases. Interaction between plant density and variety exhibited significant effect on yield and the highest yield was produced with variety G-2 at 20 plants m^{-2} Rabi seasons while the highest yield in Kharif II season was found with variety PB-1 at 60 plants m^{-2} (Table 1).

Plant density, variety and their interaction had significant effect on seed yield m^{-2} in all the three growing seasons. The highest seed yield of 113.12 and 101.99 g m^{-2} were obtained at 100 plants m^{-2} in Rabi 2005 and Kharif-II 2005 seasons, respectively while in Rabi 2005-06 season the highest (150.95 g m^{-2}) was obtained at 80 plants m^{-2} (Table 1). Seed yield (m^{-2}) increased with each successive increase in plant density up to a plant density of 100 plants m^{-2} in Rabi 2004-05 while up to 80 plants m^{-2} in Kharif-II 2005 season. In both the Rabi seasons, variety G-2 produced higher seed yield than variety PB-1 while in Kharif-II 2005 season, variety PB-1 gave higher seed yield (114.19 g m^{-2}) than variety G-2. Variety G-2 produced about 41 and 22% higher seed yield m^{-2} than variety PB-1 in Rabi 2004-05 and Rabi 2005-06 seasons, respectively. On the other hand, in Kharif-II 2005 season variety PB-1 produced about 56% higher yield than variety G-2 (Table 1). Interaction of plant density and variety showed that in Rabi 2004-05 season, variety G-2 at 100 plants m^{-2} produced highest seed yield (148.85 g m^{-2}) and variety PB-1 at 20 plants m^{-2} gave the lowest (48.58 g m^{-2}). In Kharif-II 2005 season, variety PB-1 at 100 plants m^{-2} produced highest seed yield (151.06 g m^{-2}) and variety G-2 at 20 plants m^{-2} produced the lowest (34.63 g m^{-2}). Whereas, in Rabi 2005-06 season, variety G-2 at 80 plants m^{-2} produced the highest seed yield (185.22 g m^{-2}) while variety PB-1 at 20 plants m^{-2} had the lowest (88.33 g m^{-2}).

Protein and mineral content: Protein and mineral contents in soybean seed showed quadratic response to plant density (Fig. 1, 2). The response curve showed that the protein content decreased with increase in plant density for both the varieties up to 80 or 100 plants m^{-2} depending on the season and then increased with further increase in density (Fig. 1a, b) while the reverse occurred with other nutrients. The phosphorus and potassium content increased with increase in plant density up to 120 plants m^{-2} for both the varieties in all the three seasons although the increase was very minimal above a density of 100 plants m^{-2}. Therefore, the phosphorus and potassium content tended to show a quadratic response with plant density (Fig. 2). It was found from the regression analysis that the coefficients of determinations (R^2 values) for the relationship of protein content and plant density for variety G-2 and PB-1 were 0.78 and 0.62 in Rabi 2004-05, 0.90 and 0.87 in Kharif-II 2005 and 0.79 and 0.69 in Rabi 2005-06 seasons, respectively

Table 1: Effect of plant density, variety and their interaction on seed yield of soybean in Rabi 2004-05, Kharif-II 2005 and Rabi 2005-06 seasons

	Seed yield (g plant^{-1})			Seed yield (g m^{-2})		
Treatment	Rabi 2004-05	Kharif-II 2005	Rabi 2005-06	Rabi 2004-05	Kharif-II 2005	Rabi 2005-06
Plant density (Plants m^{-2})						
20	3.40a	2.51a	11.11a	55.24e	53.69e	105.60e
40	2.68b	2.37a	7.75b	83.91d	59.04d	125.91c
60	1.89c	2.32ab	7.44b	93.11c	82.39c	135.20b
80	1.73d	2.15b	7.41b	101.11b	100.76ab	150.95a
100	1.56e	2.11b	5.45c	113.12a	101.99a	126.71c
120	1.44e	1.77c	4.52d	106.75a	96.15b	114.19d
S	0.044	0.069	0.170	1.776	1.595	1.768
F-test	**	**	**	**	**	**
CV (%)	5.03	7.71	5.72	4.70	4.75	3.43
Variety						
G-2	2.76a	1.13b	7.88a	116.52a	50.48b	142.42a
PB-1	1.48b	3.28a	6.68b	68.57b	114.19a	110.42b
S $\bar{x}$	0.033	0.068	0.034	1.081	0.214	0.585
F-test	**	**	**	**	**	**
CV (%)	6.68	12.99	3.06	4.95	1.10	1.96
Plant density (plants m^{-2})×Variety						
20×G-2	4.24a	1.19d	11.57a	61.91f	34.63g	122.86de
20×PB-1	2.57c	3.07c	10.64b	48.58g	72.76e	88.33h
40×G-2	3.73b	1.15d	7.41de	109.93c	33.51g	148.91c
40×PB-1	1.63e	3.47ab	7.47de	57.88f	84.58d	102.90g
60×G-2	2.55c	1.19d	9.23c	114.03bc	50.10f	157.78b
60×PB-1	1.23fg	3.47a	5.86f	72.18c	114.67c	112.62f
80×G-2	2.07d	1.07d	8.12d	119.50b	83.58d	185.22a
80×PB-1	1.39f	3.19bc	6.70e	82.71d	117.94c	116.67ef
100×G-2	2.04d	1.25d	6.82e	148.85a	52.93f	126.75d
100×PB-1	1.08gh	3.19bc	4.09g	77.40de	151.06a	126.67d
120×G-2	1.90d	0.93d	3.74g	144.91a	48.15f	112.99f
120×PB-1	0.97h	3.01c	5.30f	72.59c	144.16b	115.34ef
S $\bar{x}$	0.063	0.108	0.241	2.511	2.256	2.500
F-test	**	ns	**	**	**	**
CV (%)	5.03	8.49	5.72	4.70	4.75	3.43

**Significant at 1% level, ns = Not significant, S $\bar{x}$ = Standard Error of Mean, Values having same letter(s) do not differ significantly at 5% level

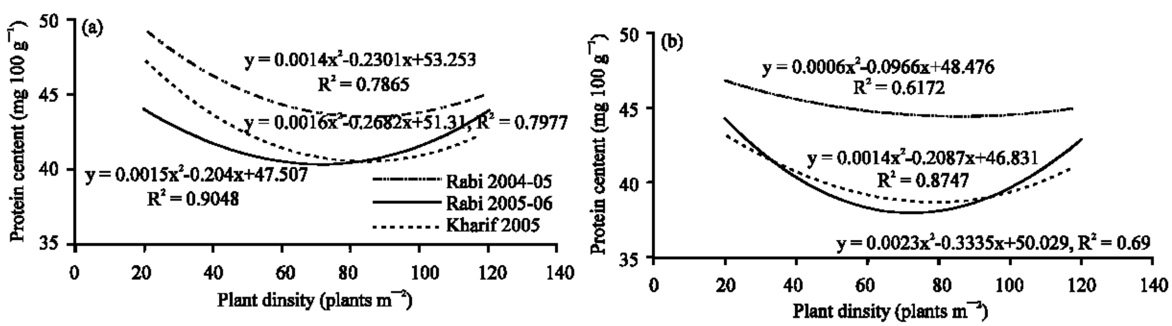

Fig. 1: Relationship of seed protein content with plant density of two soybean varieties (a) G-2 and (b) PB-1 in Rabi 2004-05, Kharif 2005 and Rabi 2005-06 seasons

(Fig. 1) The R^2 values for the phosphorus content and plant density for variety G-2 and PB-1 were 0.96 and 0.91 in Rabi 2004-05, 0.68 and 0.79 in Kharif-II 2005 and 0.97 and 0.93 in Rabi 2005-06 seasons (Fig. 2), respectively. The regression analysis of calcium content and plant density showed that the R^2 values for variety G-2 and PB-1 were 0.99 and 0.98 in Rabi 2004-05, 0.72 and 0.97 in Kharif-II 2005 and 0.98 and 0.97 in Rabi 2005-06 seasons (Fig. 2a), respectively. The relationship of potassium content with plant density showed quadratic response with R^2 values for variety G-2 and PB-1 were 0.88 and 0.07 in Rabi 2004-05, 0.72 and 0.86 in Kharif-II 2005 and 0.99 and 0.94 in Rabi 2005-06 seasons (Fig. 2a, b), respectively. The regression analysis showed that the R^2 values for the relationship of sulphur content and plant density for variety G-2 and PB-1 were 0.87 and 0.62 in Rabi 2004-05, 0.86 and 0.91 in Kharif-II 2005 and 0.73 and 0.26 in Rabi 2005-06 seasons (Fig. 2), respectively. The R^2

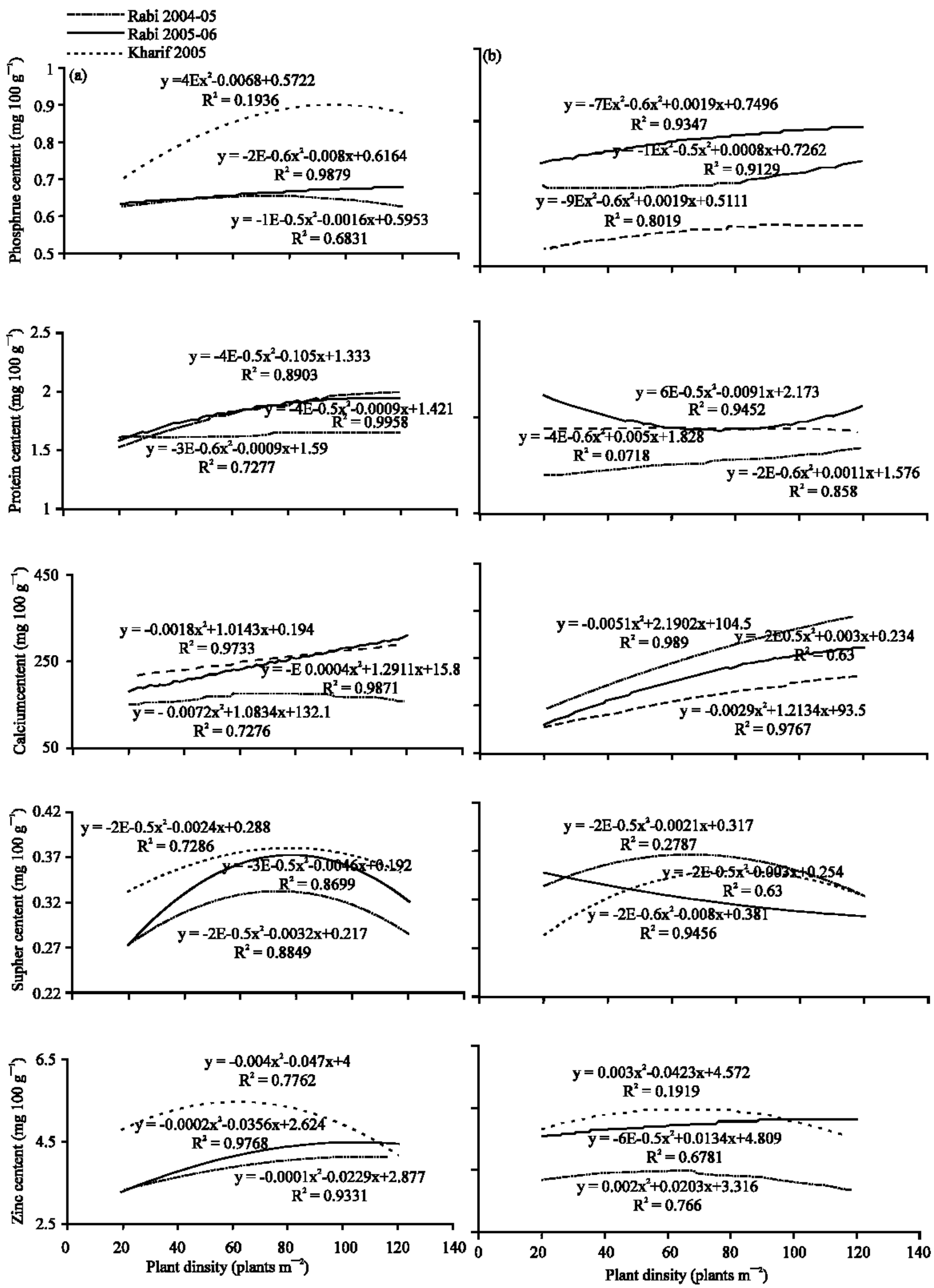

Fig. 2: Relationships of phosphorus, potassium, calcium, sulphur and zinc content in seed with plant density of two soybean varieties (a) G-2 and (b) PB-1 in Rabi 2004-05, Kharif 2005 and Rabi 2005-06 seasons

Table 2: Relationship of protein content with other mineral contents of soybean seed under different plant densities and variety

Season	Phosphorus	Calcium	Potassium	Sulphur	Zinc
Rabi 2004-05	-0.280ns	-0.560**	-0.384*	-0.398*	-0.361*
Kharif-II 2005	0.212ns	-0.343*	-0.191ns	-0.386*	-0.374*
Rabi 2005-06	-0.138ns	-0.487**	-0.297ns	-0.593**	-0.322ns

*p<0.05, **p<0.01, ns = Not significant, n = 36

values for the zinc content and plant density for variety G-2 and PB-1 were 0.97 and 0.67 in Rabi 2004-05, 0.77 and 0.19 in Kharif-II 2005 and 0.93 and 0.76 in Rabi 2005-06 seasons (Fig. 2), respectively.

Relationships of seed protein with other mineral contents in seed: Correlation matrix showed that seed protein content had negative relationship with phosphorus, calcium, potassium, sulphur and zinc contents in soybean seed (Table 2). This correlation was highly significant for Ca and S but not for P for all the three seasons. Potassium showed significant relationship in Rabi 2004-05 only while Zn showed significant relationship only in Rabi 2004-05 and Kharif-I 2005 seasons but not in the Rabi 2005-06 season.

DISCUSSION

In Bangladesh, the recommended plant density for soybean (variety G-2 or PB-1) are 66 and 50 plants m^{-2} for Rabi and Kharif-II seasons, respectively (BARI, 2005) but the present study showed the highest yield required a plant density of between 80 and 100 plants m^{-2} in all the three seasons for both the varieties. This high plant density for maximum yield might be related to the differences in site and soil as other management practices were as per recommendation. Rahman and Hanif (2006) also obtained the highest yield of 2.2 t ha^{-1} at 20×5 cm spacing (i.e., at 100 plants m^{-2}) at the same location which corroborates the present results. Therefore, the lower plant density of 50 or 66 plants m^{-2} is not suitable for producing higher yield in this location for the said cultivars. The average yield of soybean in Bangladesh is far below than our yield and this yield difference could be mainly related to plant population.

Maximum yield in soybean could be obtained at a plant density that could provide 95% solar radiation interception by R5 stage (Egli, 1998) or by R1 stage (Lee, 2006). The higher yield at higher plant density in this study was therefore, possible due to early canopy closure and higher dry matter accumulation at R5 stage. Wells (1991) reported that the crop that could reach canopy closure prior to seed development could contribute to high TDM production and seed yield. Although light interception was not measured in this study, the study at Canterbury, New Zealand confirms that the crop at higher plant densities reached the canopy closure before the start of seed filling and thus contributed to high yield than those at low PPD (Rahman *et al*., 2005b).

The recommended plant density in Brazil for the summer and winter seasons are 33 and 66 plants m^{-2} (FAO, 1994) and the plant density used in the mid-southern USA is 50 plants m^{-2} (Bowers *et al*., 2000). The optimum plant density variation in different countries might be due to difference in stature of the variety used in the studies. The crop under the present study required more population to attain optimum leaf area for intercepting solar radiation due to soil and environmental variation of the growing environment (Holshouser and Whittaker, 2002).

The present study showed curvilinear relationship of seed protein content and seed yield with plant density. Similar result was also reported by Rahman *et al*. (2005a) in soybean under temperate environment at Canterbury, New Zealand. In the present study, all the minerals (P, K, Ca, S and Zn) showed curvilinear relationship with plant density and the fitted curves were similar to that for seed yield. Thus it appears that the plant density that favours higher yield also helps increasing phosphorus, calcium, potassium, sulphur and zinc contents in seed but reduces seed protein content. The present study showed that seed protein content was inversely related with P, K. Ca, S and Zn content in soybean which could be supported by previous reports (Gayler and Sykes, 1985; Sexton *et al*., 1998). Although oil content was not measured in this study, a large body of literature concluded that seed protein and oil content were inversely related (Jian and Xinmin, 1992; Xu *et al*., 1996; Muhammad *et al*., 2009). Thus the present study indicates that highest oil and mineral contents in soybean could be obtained at a plant density that gives highest seed yield. Several mineral elements such as Ca, K, Zn, S and P play very vital role in human and animal nutrition. Protein and oil are also important constituents in seed which have very important commercial value. Thus, proper agronomic management should be directed to improve nutritional quality of soybean seed for human consumption. The present study reveals that the plant density that gives high yield can also be considered for high minerals and oil contents. On the other hand, for obtaining higher protein content, seed yield needs to be sacrificed to some extent. However, maximum yield could be obtained by adjusting plant density with proper agronomic practices to ensure early canopy closure for higher solar radiation interception. The optimization in plant density and different agronomic management practices would ensure high yield of soybean seed with high quality.

CONCLUSION

Present study reveals that there is no trade off between yield and nutritional quality (except protein content) of soybean seed. Therefore, the highest seed yield and mineral contents could be obtained with a plant density between 80 and 100 plants m^{-2} depending upon the variety and growing season. While for obtaining higher seed protein content a lower seeding density of 60 plants m^{-2} could be considered sacrificing yield.

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REFERENCES

BARI, 2005. Handbook of Agrotechnology. Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh, pp: 155-160.

Bowers, G.R., J.L. Rabb, L.O. Ashlock and J.B. Santini, 2000. Row spacing in the early soybean production system. Agron. J., 92: 524-531.

Bremner, J.M. and C.S. Mulvaney, 1982. Total Nitrogen. In: Methods of Soil Analysis: Chemical and Microbiological Properties, Page, A.L., R.H. Miller and D.R. Keeney (Eds.). Amercen Social Argonomy, Madison, WI. USA., pp: 595-624.

Cho, Y.S. and S.D. Kim, 2010. Growth parameters and seed yield compenets by seeding time and seed density of non-/few branching soybean cultivars in drained paddy field. Asian J. Plant Sci., 9: 140-145.

Daroish, M., Z. Hassan and M. Ahad, 2005. Influence of planting dates and plant densities on photosynthesis capacity, grain and biological yield of soybean [*Glycine max* (L.) Merr.] in karaj, Iran. J. Agron., 4: 230-237.

Egli, B., 1988. Plant density and soybean yield. Crop Sci., 28: 977-981.

El-Din, G.M.S., K.A. El-Douby, E.A. Ali and M.S.A. Mohamed, 1997. Response of some soybean varieties to plant population density. Ann. Agric. Sci., 35: 131-142.

FAO., 1994. Tropical Soybean: Improvement and Production. Food and Agriculture Organization, Rome.

Gayler, K.R. and G.E. Sykes, 1985. Effects of nutritional stress on the storage proteins of soybean. Plant. Physiol., 78: 582-585.

Grichar, W.J., 2007. Row spacing, plant population and cultivar effects on soybean production along the Texas Gulf Coast. Crop Manage., 10.1094/CM-2007-0615-01-RS

Holshouser, D.L. and J.P. Whittaker, 2002. Plant population and row spacing effects on early soybean production systems in the mid-Atlantic USA. Agron. J., 94: 603-611.

Holshouser, D.L. and B.P. Jones, 2003. Early-maturing double crop soybean requires higher plant population to meet leaf area requirements. Crop Manage., 10.1094/CM-2003-0408-01-RS

Jadhav, P.J., A.S. Jadhav and S.M. Bachchhav, 1994. Effects of nitrogen, row spacings and plant densities on the yield and quality of soybean. J. Maharashtra Agric. Univ., 19: 75-77.

Jian, W. and W. Xinmin, 1992. The accumulation of fat and protein in soybean and the distribution of climatic factors during the flowering to ripening stage in the Heihe region. Soybean Sci., 11: 240-246.

Kang, Y.K., M.R. Ko, N.K. Cho and Y.M. Park, 1998. Effect of planting date and planting density on growth and yield of soybean in Cheju island. Korean J. Crop Sci., 43: 44-48.

Khan, A.Z., P. Shah, S.K. Khalil and F.H. Taj, 2003. Influence of planting date and plant density on morphological traits of determinate and indeterminate soybean cultivars under temperate environment. J. Agron., 2: 146-152.

Lee, C.D., 2006. Reducing row widths to increase yield: Why it does not always work. Crop Manage., 10.1094/CM-2006-0227-04-RV

McDonald, M.B., 1999. Seed deterioration: Physiology, repair and assessment. Seed Sci. Technol., 27: 177-237.

Mehmet, O.Z., 2008. Nitrogen rate and plant population effects on yield and yield components in soybean. Afr. J. Biotechnol., 7: 4464-4470.

Miles, D.F., D.M. Tekrony and D.B. Egli, 1988. Changes in viability, germination and respiration of freshly harvested soybean seed during development. Crop Sci., 28: 700-704.

Muhammad, A., S.K. Khalil, K.B. Marwat, A.Z. Khan, I.H. Khalil, Amanullah and S. Arifullah, 2009. Nutritional quality and production of soybean land races and improved varieties as affected by planting dates. Pak. J. Bot., 41: 683-689.

Olsen, S.R. and L.M. Sommers, 1982. Phosphorus. In: Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties, Page, A.L., R.H. Miller and D.R. Keeney (Eds.). American Society of Agronomy, Madison, WI.

Prasad, J.V.N.S., N.V. Ramaiah and V. Satyanarayana, 1993. Response of soybean (*Glycine max*) to varying levels of plant density and phosphorus. Indian J. Agron., 38: 494-495.

Rahman, M.M., M.G. Mwakangwale, J.G. Hampton and M.J. Hill, 2004. The effect of plant density on seed yield of two cool tolerant soybean cultivars in Canterbury. Agron. N. Z., 34: 149-159.

Rahman, M.M., M.G. Mwakangwale, J.G. Hampton and M.J. Hill, 2005a. Plant density affects soybean seed quality. Seed Sci. Technol., 33: 521-525.

Rahman, M.M., J.G. Hampton and M.J. Hill, 2005b. Growth response of cool tolerant soybean to variation in sowing date. Agron. N.Z., 35: 81-96.

Rahman, M.M. and M.A. Hanif, 2006. Effect of row spacing and phosphorus level on soybean seed yield and quality. Bangladesh J. Seed Sci. Technol., 10: 69-75.

Rigsby, B. and J.E. Board, 2003. Identification of soybean cultivars that yield well at low plant populations. Crop Sci. J., 43: 234-239.

Sexton, P.J., N.C. Paek and R.M. Shibles, 1998. Soybean sulfur and nitrogen balance under varying levels of available sulfur. Crop Sci., 38: 975-982.

Shafshak, S.E., G.M. Shams-El-Din, M.Z. Hassan and M.S. Mohamed, 1997. Evaluation of six soybean genotypes under different population densities and two sowing dates. Ann. Agric. Sci., 35: 115-130.

Singh, G., 2010. Replacing rice with soybean for sustainable agriculture in the indo-gangetic plain of India: Production technology for higher productivity of soybean. Int. J. Agric. Res., 5: 259-267.

UNDP/FAO, 1988. Land resources appraisal of bangladesh for agricultural development report No. 2. Agro-ecological regions of Bangladesh. United Nations Development Program and Food and Agriculture Organization, pp: 212-221.

Wells, R., 1991. Soybean growth response to plant density: Relationships among canopy photosynthesis, leaf area and light interceplistion. Crop Sci., 31: 755-761.

Xu, Y.H., Z.H. He and Y.Q. Xin, 1996. Study on eco-geographical variation in chemical composition of soybeans. Soybean Sci., 15: 119-125.

Yang, C.M. and M.J. Fan, 1996. Soybean yield response to planting date and climatic factors. Chinese J. Agro-Meteor., 3: 9-16.

Yin, X. and T.J. Vyn, 2005. Relationships of isoflavone, oil and protein in seed with yield of soybean. Agron. J., 97: 1314-1321.

Zaimoglu, B., H.H. Arioglu and M. Arslan, 2004. Effects of seed quality on plant population and seed yield of double cropped soybean in the Mediterranean region of Turkey. Asian J. Plant Sci., 3: 574-577.