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Impact of foliar fertilization on growth, yield, nutrient dynamics and seed quality of soybean

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Abstract

The study hypothesized that foliar fertilization reduced nutrient depletion from leaves during seed development stage and thereby enhancing soybean yield and seed quality. To evaluating this, the experiment included seventeen treatments combination of nitrogen, phosphorus, potassium, sulphur and boron (NPKSB) aiming to determine the optimum foliar fertilizer concentration for improving growth, nutrient composition, yield and seed quality of soybean. The experiment was set in randomized complete block design (RCBD) with three replications and nutrient was sprayed during the seed filling period of soybean. Results of the experiment indicated that soybean plants treated with 240-200-400-350-200 mg L^{-1} of NPKSB in water exhibited higher growth values including roots weight (0.669 g), leaf weight (3.319 g), stem weight (4.661 g), pod weight (4.647 g) and whole plant weight (13.32 g). Additionally, this treatment produced the highest seed yield of2684 kg ha^{-1}. Foliar fertilization at this concentration also improved the nutrient composition of the seed and enhanced seed quality, as evidenced by higher protein content (42.05%), seed viability (97.98%) and vigour. However, excessive concentration of foliar fertilizer may lead to leaf burn and negatively impact the yield and seed quality of soybean.

Keywords: Foliar fertilizer, soybean, yield, seed quality

Introduction

Soybean (*Glycine max* [L.] (Merr.) is multipurpose grain legume widely used all over the world as it has dietetic, industrial, medicinal and many other economic importance. Consumption of soybean products has been linked to decrease of some dangerous diseases such as heart diseases and certain types of cancer (Wu *et al.* 1998). It is the only grain legume that contains the highest proportion of protein and oil (David, 1984). Thus, in modern agriculture soybean folds dual importance; it serves as a source of oil and seed protein for human consumption as well as a protein-rich feed for animals. In the future, soybean may also emerge as a significant source for bio-fuel production (JFA 2007).

Although, demand of soybean is increasing day by day in Bangladesh, its average yield is decreasing due to many biotic and abiotic causes (AVRDC 1990). For example, soil fertility is declining as a result of continuous crop cultivation. In the soils, the main nutritional limitations are nitrogen, phosphorus and potassium. Other nutrients like sulphur and boron may also be limiting when the soil is planted for several successive years, due to crop removal (Penas and Wiese 1996). Therefore, it is essential to apply fertilizers during soybean cultivation to replenish the soil nutrients.

Apart from soil fertilization, foliar fertilization has been to be a unique means to replenishing the reservoir of nutrients in leaves of legumes during pod development stage. It is evident that large yield (27-31%) increased from foliar application of NPKS fertilizer mixture during reproductive stages of soybean (Garcia and Hamway 1976). They suggested that root activity decreased during the pod-filling stage, limiting nutrient uptake and preventing optimal yields. Foliar fertilization during this critical period was proposed as a method of increase total nutrients availability without relying on root absorption.

The efficiency of nutrient uptake through foliar applications is not well understood. Additionally, it is crucial to determine the optimal proportion of each nutrient to achieve the desired effects of foliar fertilization. Therefore, the objective of this study was to identify the effective proportion of NPKSB foliar fertilizer to enhance the growth, yield and seed quality of soybean.

Materials and methods

The field trial was conducted at research field of Bangabandhu Sheikh Mujibur Rahaman Agricultural University, Gazipur, Bangladesh during rabi season as

a subsequent experiment of previous five experiments. From the results of those experiments, it was suggested for further research to confirm and to determine optimum proportion for foliar fertilization of soybean. Based on the previous results, the present experiment consisted of 17 treatment combination including control as presented in Table 1.

The experiment was arranged in randomized complete block design (RCBD) with three replications. Unit plot size was 2.4 m × 2 m, plant to plant distance was 5 cm, row to row distance was 30 cm. The soybean seeds were planted on 13 January, 2010. The excess seedlings were thinned out and necessary gaps were filled out within 20 days after sowing. Light irrigation was given just after sowing to establish the stand properly. Two weeding were also done at 20 and 35 days after sowing. Insecticide and fungicide were sprayed as precautionary measure to protect the crop from insect and diseases. Foliar fertilization was done according to the morphological stage of plant development between stages R_3 and R_7 as described by Fehr *et al.* (1971).

The soybeans were harvested from each unit plot at 83 days after sowing for growth analysis. For growth data viz. dry weight of leaf, shoot, root, pod and total dry weight were recorded. For determination of yield contributing characters of soybean, seven plants were randomly selected from each plot and number of pods per plant, seeds per pod, 100 seeds weight seed and yield per plant were recorded. Seed yield of soybean was determined by harvesting whole plot and converted into kg ha $^{-1}$ at 7.5 % moisture content. Grain quality was determined considering protein and oil content in seed. The oil percentage of seed was estimated as per Gadgil *et al,* (1980). Nitrogen percentage of soybean seed was estimated by Kjeldahl method. The estimated result was multiplied by the factor 6.25 to obtained protein percent. Seed quality of freshly harvested soybean seeds were assessed by germination test (Krishnasamy and Seshu, 1990) and electrical conductivity test as per Ali *et al*. (2005).

Statistical analysis: All data were subjected to statistical analysis by analysis of variance (ANOVA). Microsoft EXCEL and MSTAT software programs were used

Table 1. Treatment combinations containing element of nitrogen, phosphorus, potassium, sulphur and boron for foliar fertilization

Treatments	Treatment combination (mg L^{-1} water)				
	N	P	K	S	B
T_0	0	0	0	0	0
T_1	0	200	400	400	200
T_2	210	200	400	400	200
T_3	240	200	400	400	200
T_4	270	200	400	400	200
T_5	240	0	400	400	200
T_6	240	150	400	400	200
T_7	240	200	400	400	200
T_8	240	250	0	400	200
T_9	240	200	300	400	200
T_{10}	240	200	500	400	200
T_{11}	240	200	400	0	200
T_{12}	240	200	400	350	200
T_{13}	240	200	400	450	200
T_{14}	240	200	400	400	0
T_{15}	240	200	400	400	250
T_{16}	240	200	400	400	300

wherever appropriate and the means were compared according to Duncan's Multiple Range Test (DMRT). Functional relationships among the parameters were established through correlation and regression analysis by using SPSS software program.

Results and discussion

Foliar fertilizer application had advantages over control as it brought direct improvement in growth of soybean plant (Figure. 1). Plants treated with 240-200-400-350-200 NPKSB mg L^{-1} water recorded higher growth values indicating as an optimal requirement for better growth of soybean. The dry matter accumulation in roots (0.669 g), leaves (3.319 g), stem (4.661 g), pods (4.647 g) and whole plant (13.32 g) reached at peak which received this concentration as foliar fertilization. The application of 240-200-400-350-200 NPKSB mg L^{-1} water to soybean plants might increase chlorophyll content, carboxylating activity, net photosynthesis and protein synthesis. These illustrated the integral role of foliar nutrients in better processes of dry matter accumulation in soybean plants (Sharma and Tanuja, 1990). Effect of foliar fertilizer on

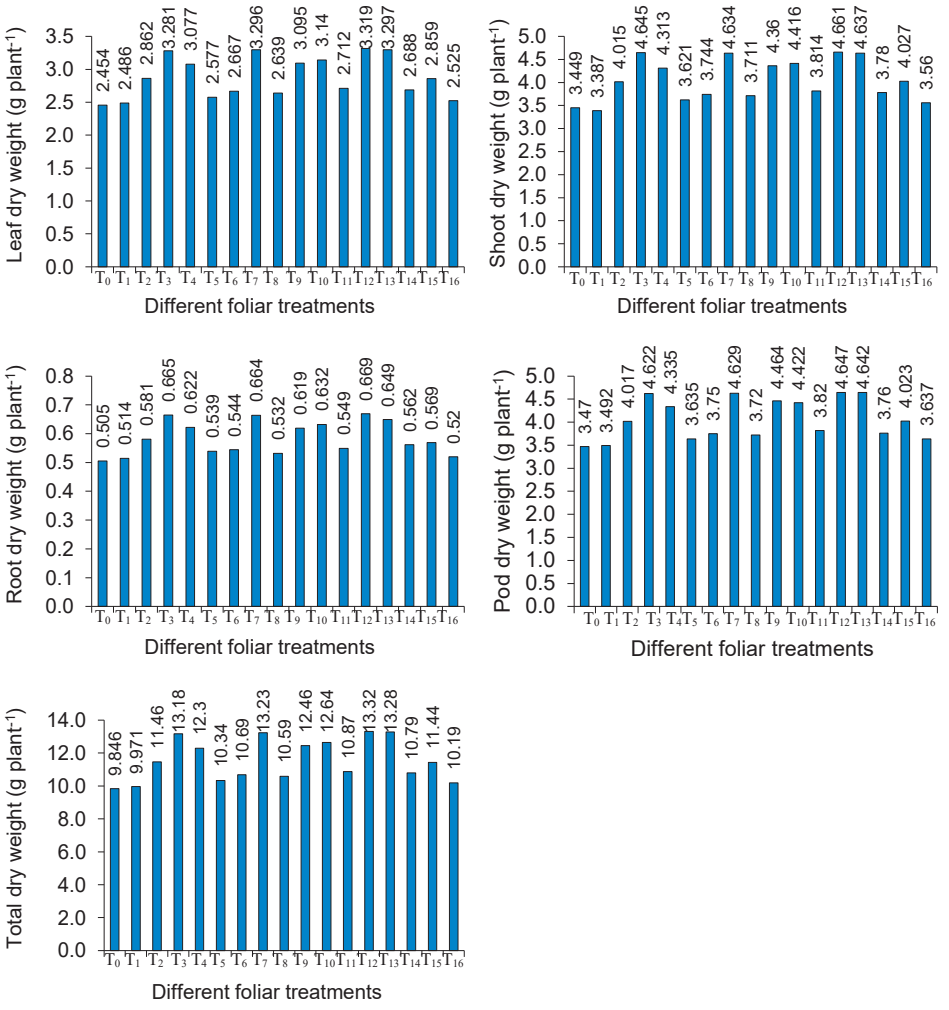


Figure 1. Dry matter accumulation of soybean plants under different concentrations of foliar fertilizer application.

Where,
T_0=0-0-0-0-0; T_1=0-200-400-400-200; T_2=210-200-400-400-200; T_3=240-200-400-400-200; T_4=270-200-400-400-200; T_5=240-0-400-400-200; T_6=240-150-400-400-200; T_7=240-200-400-400-200; T_8=240-250-0-400-200; T_9=240-200-300-400-200; T_{10}=240-200-500-400-200; T_{11}=240-200-400-0-200; T_{12}=240-200-400-350-200; T_{13}=240-200-400-450-200; T_{14}=240-200-400-400-0; T_{15}=240-200-400-400-250; T_{16}=240-200-400-400-300 NPKSB mg L^{-1} water.

general growth and development of crop plant has been studied by other workers (Pilbean and Kirkbz 1983). These elements involve in hormone synthesis and translocation, carbohydrate metabolism and DNA synthesis which probably contributed to additional growth compared to controls (Krueger *et al.*, 1987).

The proportion of nutrient accumulated in soybean seed at maturity for different treatments are reported in Table 2. In general, nutrient accumulation in soybean seeds increased with higher concentration of foliar NPKSB application peaking at 240-200-400-350-200 mg L^{-1} NPKSB in water after which it declined slightly. The contribution of this foliar nutrient combination in the highest seed nutrient accumulation might be due to its better growth when it was applied at reproductive stage of soybean. Foliar application at reproductive stage could increase nutrient supplies at a time when root systems are not well developed (Demooy *et al*. 1973). Such nutrient supplies due to foliar fertilization also increased nutrient accumulation in soybean seed.

Nutrient accumulation in seed has great implication in yield formation as there are positive relationship between seed nutrient content and yield of soybean (Figure 2). The yield increases from foliar application of nutrient solution during reproductive period resulted primarily from an increase in number of harvestable seeds and then increase in seed nutrient content (Lawn and Brun, 1974).

Foliar fertilizer application caused significant increase in number of pods per plant, number of seeds per pod, seed size and seed yield of soybean as compare with control treatment. Like growth attributes, the treatment combination 240-200-400-350-200 NPKSB mg L^{-1} water

Table 2. Accumulation of nutrient in soybean seed as influenced by foliar fertilizer application

Treatment combination	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Sulphur (%)	Boron (ppm)
T_0	5.83 j	0.193 h	0.54 e	0.170 g	73.16 fg
T_1	7.027 fg	0.260 b-e	0.64 cd	0.190 f	92.86 cd
T_2	7.23 efg	0.251 def	0.65 cd	0.210 e	82.76 ef
T_3	8.46 ab	0.276 ab	0.73 b	0.270 ab	108.60 b
T_4	7.96 cd	0.263 b-e	0.63 cd	0.190 f	82.93 ef
T_5	6.06 ij	0.254 c-f	0.64 cd	0.230 de	101.10 bc
T_6	6.13 ij	0.271 abc	0.61 d	0.140 h	64.82 gh
T_7	8.26 bc	0.273 abc	0.72 b	0.260 ab	88.53 de
T_8	7.50 def	0.261 b-e	0.63 cd	0.250 bc	102.90 b
T_9	6.31 ij	0.245 ef	0.62 cd	0.175 fg	100.80 bc
T_{10}	7.04 fg	0.237 f	0.64 cd	0.172 g	80.78 ef
T_{11}	7.73 d	0.180 h	0.61 d	0.244 cd	66.08 gh
T_{12}	8.85 a	0.289 a	0.80 a	0.281 a	119.03 a
T_{13}	7.55 de	0.266 bcd	0.68 bc	0.261 bc	104.70 b
T_{14}	6.47 hi	0.212 g	0.63 cd	0.179 fg	62.86 h
T_{15}	6.83 gh	0.252 def	0.61 d	0.144 h	68.83 gh
T_{16}	6.91 gh	0.241 f	0.63 cd	0.145 h	80.76 ef
CV (%)	3.74	7.35	4.01	5.28	5.12

Values within same column with different letters are significantly different according to DMRT at 5% level of significance.

Where,

T_0=0-0-0-0-0; T_1=0-200-400-400-200; T_2=210-200-400-400-200; T_3=240-200-400-400-200; T_4=270-200-400-400-200; T_5=240-0-400-400-200; T_6=240-150-400-400-200; T_7=240-200-400-400-200; T_8=240-250-0-400-200; T_9=240-200-300-400-200; T_{10}=240-200-500-400-200; T_{11}=240-200-400-0-200; T_{12}=240-200-400-350-200; T_{13}=240-200-400-450-200; T_{14}=240-200-400-400-0; T_{15}=240-200-400-400-250; T_{16}=240-200-400-400-300 NPKSB mg L^{-1} water.

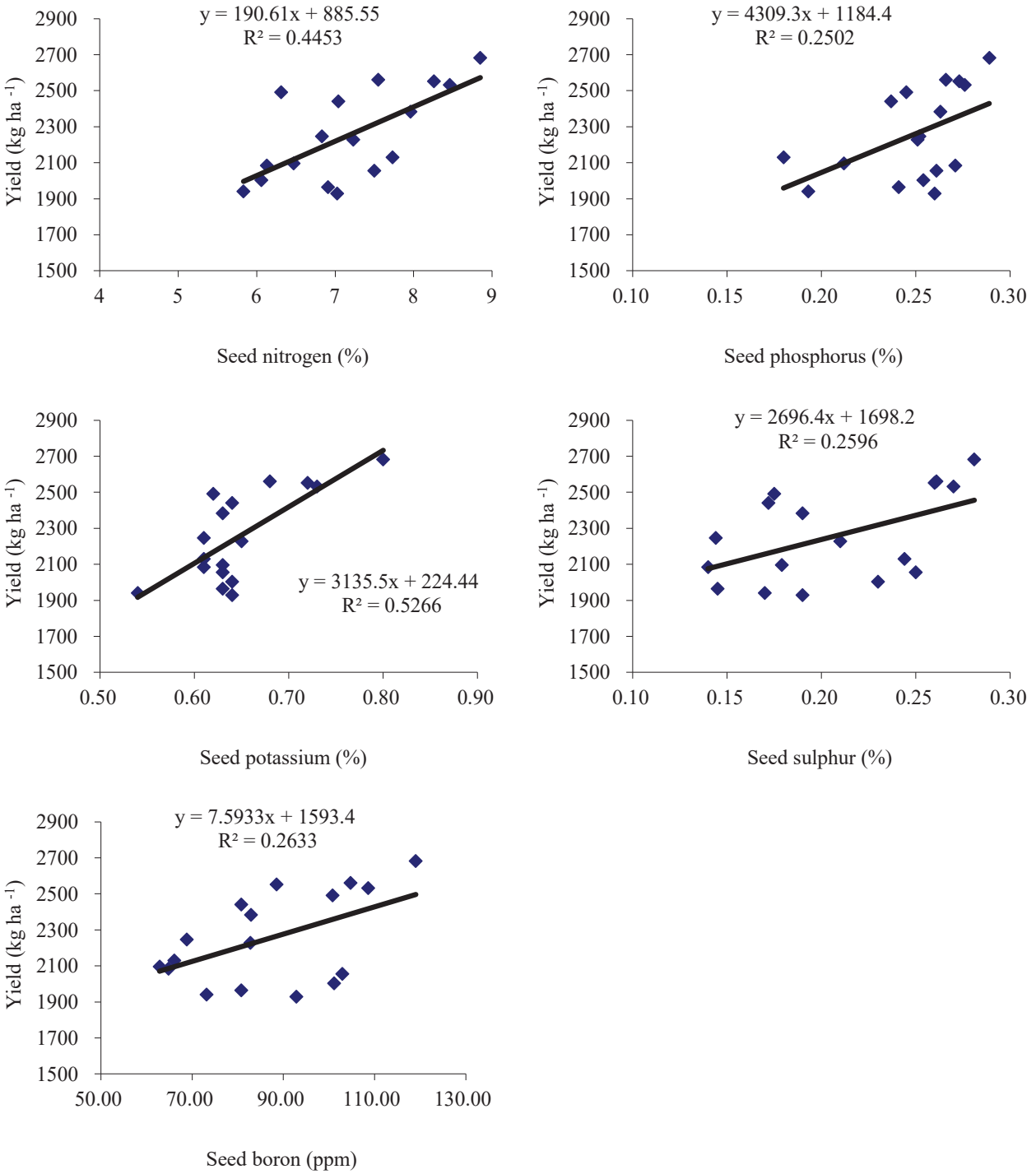


Figure 2. Relationship between seed nutrient concentration and seed yield of soybean.

produced the highest number of pods per plant (42.62), seeds per pod (2.55), seed size (11.70 g) and ultimately seed yield (2684 kg ha^{-1}) as shown in Table 3. The superiority of the treatment combination in improving yield attributes and seed yield of soybean might be attributed to its higher content of macro (NPKS) and micro (B) element in plant tissue. Therefore, this affects the photosynthesis of leaves which may account for higher accumulation of metabolites in different organs of soybean plants (Schon and Blevins 1990). Consequently, promoting rapid growth, increasing pod formation and seed development and finally improving the yield of soybean. The results suggested that soybean plants must be provided with a balanced nutrient supply via foliar application during seed filling, because photosynthate sugar is channeled to the developing seeds on the expense of the roots and nodules, which led to receive little food to serve as energy source for taking up nutrients from the soil (Garcia and Hanway 1976).

Concerning the effect of foliar fertilizer treatments on protein and oil percentage of soybean seed, the effect was very inconsistent on oil content. The effect was however consistent on protein percentage where the treatment 240-200-400-350-200 NPKSB mg L^{-1} water showed the highest percentage (42.05) of protein as compared with the other treatments applied as foliar fertilizer (Table 4). The increase in protein content at this treatment may be ascribed as better involvement of foliar NPKSB in the process of protein synthesis. For example, N and S are part of protein, P activates coenzymes for amino acid production that are used in protein synthesis. However, K activates enzymes to metabolize carbohydrates to manufacture amino acids and proteins. Nevertheless, B is required for symbiotic nitrogen fixation and reduction in nitrates for protein synthesis (Abady *et al.* 2008).

Table 3. Yield attributes and seed yield of soybean as influenced by different concentrations of foliar fertilization

Treatment combinations	Pods $plant^{-1}$	Seeds pod^{-1}	100 seed weight (g)	Seed yield (kg ha^{-1})
T_0	30.72 j	2.01 h	7.621 g	1942 k
T_1	31.38 j	2.21 g	7.750 g	1929 k
T_2	37.64 d	2.20 g	9.589 c	2228 f
T_3	42.58 a	2.39 de	10.65 b	2533 bc
T_4	40.39 b	2.31 f	8.871 c-f	2385 e
T_5	33.62 i	2.40 d	7.912 g	2004 ij
T_6	34.15 hi	2.41 d	8.261 efg	2085 gh
T_7	42.98 a	2.47 bc	10.67 b	2554 b
T_8	33.35 i	2.34 ef	8.073 fg	2056 hi
T_9	38.90 c	2.43 cd	9.036 cde	2493 cd
T_{10}	40.67 b	2.43 cd	8.921 c-f	2442 d
T_{11}	35.53 fg	2.40 d	8.228 efg	2131 g
T_{12}	42.62 a	2.55 a	11.70 a	2684 a
T_{13}	42.29 a	2.52 ab	10.40 b	2561 b
T_{14}	34.83 gh	2.39 de	9.137 cd	2097 gh
T_{15}	36.42 ef	2.48 bc	8.352 d-g	2248 f
T_{16}	37.21 de	2.49 b	8.121 fg	1965 jk
CV (%)	7.68	2.94	5.08	9.43

Values within same column with different letters are significantly different according to DMRT at 5% level of significance.

Where,
T_0=0-0-0-0-0; T_1=0-200-400-400-200; T_2=210-200-400-400-200; T_3=240-200-400-400-200; T_4=270-200-400-400-200; T_5=240-0-400-400-200; T_6=240-150-400-400-200; T_7=240-200-400-400-200; T_8=240-250-0-400-200; T_9=240-200-300-400-200; T_{10}=240-200-500-400-200; T_{11}=240-200-400-0-200; T_{12}=240-200-400-350-200; T_{13}=240-200-400-450-200; T_{14}=240-200-400-400-0; T_{15}=240-200-400-400-250; T_{16}=240-200-400-400-300 NPKSB mg L^{-1} water.

Table 4. Effects of foliar fertilizer application on grain quality of soybean

Treatment combinations (NPKSB mg L^{-1} water)	Seed protein (%)	Seed oil (%)
T_0	26.72 h	20.33 ab
T_1	32.93 ef	20.76 a
T_2	34.82 de	20.11 abc
T_3	39.05 bc	19.76 bc
T_4	37.33 bcd	20.10 abc
T_5	28.43 gh	20.24 ab
T_6	27.98 gh	20.29 ab
T_7	38.62 bc	19.62 bc
T_8	35.10 de	19.96 abc
T_9	30.39 fg	19.93 abc
T_{10}	32.57 ef	20.03 abc
T_{11}	36.74 cd	19.27 c
T_{12}	42.05 a	19.54 bc
T_{13}	39.87 ab	19.76 bc
T_{14}	30.19 fg	19.86 bc
T_{15}	32.47 ef	19.74 bc
T_{16}	31.91 f	20.28 ab
CV (%)	4.44	2.25

Values within same column with different letters are significantly different according to DMRT at 5% level of significance.

Where,
T_0=0-0-0-0-0; T_1=0-200-400-400-200; T_2=210-200-400-400-200; T_3=240-200-400-400-200; T_4=270-200-400-400-200; T_5=240-0-400-400-200; T_6=240-150-400-400-200; T_7=240-200-400-400-200; T_8=240-250-0-400-200; T_9=240-200-300-400-200; T_{10}=240-200-500-400-200; T_{11}=240-200-400-0-200; T_{12}=240-200-400-350-200; T_{13}=240-200-400-450-200; T_{14}=240-200-400-400-0; T_{15}=240-200-400-400-250; T_{16}=240-200-400-400-300 NPKSB mg L^{-1} water.

Relationship between oil concentration and grain yield was negative but it was positive between protein concentration and grain yield of soybean (Figure 3). In another relationship, it was observed that oil concentration decreases with the increase of protein concentration in soybean seed. Such relationship suggests that, for that condition in this study, factors that increase yield do not necessarily decrease oil or protein concentration. The negative correlation between oil and protein concentrations agrees with similar negative correlations found before (Burton 1985; Brumm and Hurburgh 2003).

Foliar spraying with NPKSB caused little improvement in seed viability (germination) but appeared to increase vigour of soybean seed (Figure 4). Seed viability ranged from 87.64 to 97.98 % over different treatment combinations which indicated that degree of viability of freshly harvested soybean seeds did not affect profoundly due to foliar fertilization. Seed vigour measured by electrical conductivity revealed some inconsistent values but it is fact that the treatment combination 240-200-400-350-200 mg NPKSB L^{-1} water contributed the lowest (191μ S $cm^{-1}g^{-1}$) electrical conductivity of leachates of fresh soybean seed. As lowest is the electrical conductivity value highest is the vigour index (Lowe and Ries, 1972), high vigour seeds harvested from this treatment might be due to high accumulation of metabolites and nutrients in seeds harvested from well-proportioned NPKSB foliar fertilization.

Beneficial effects on seed vigour obtained from this foliar application of NPKSB may be attributed to their

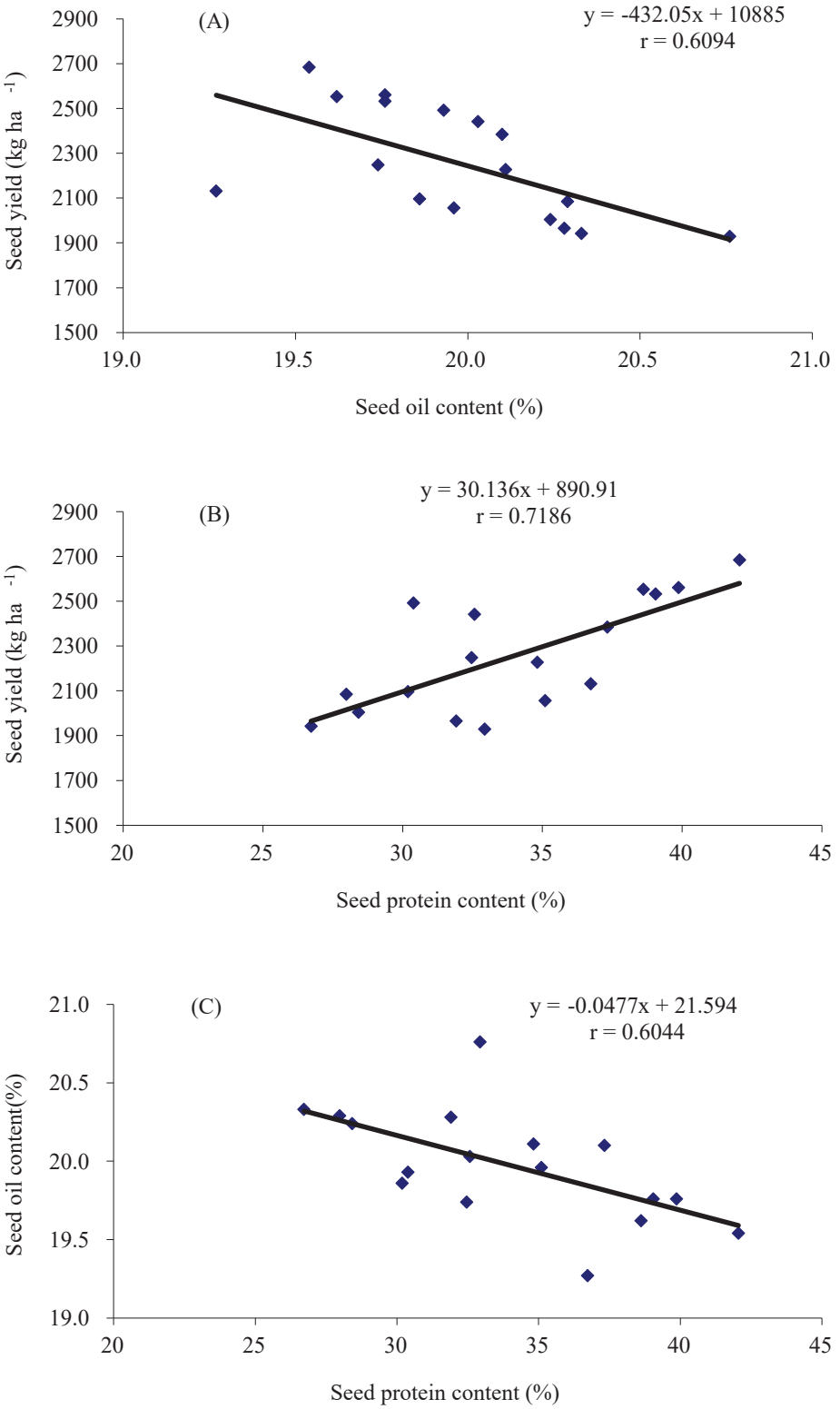


Figure 3. Relationship between (A) oil and seed yield, (B) protein and seed yield, (C) oil and seed protein under foliar fertilizer application of soybean.

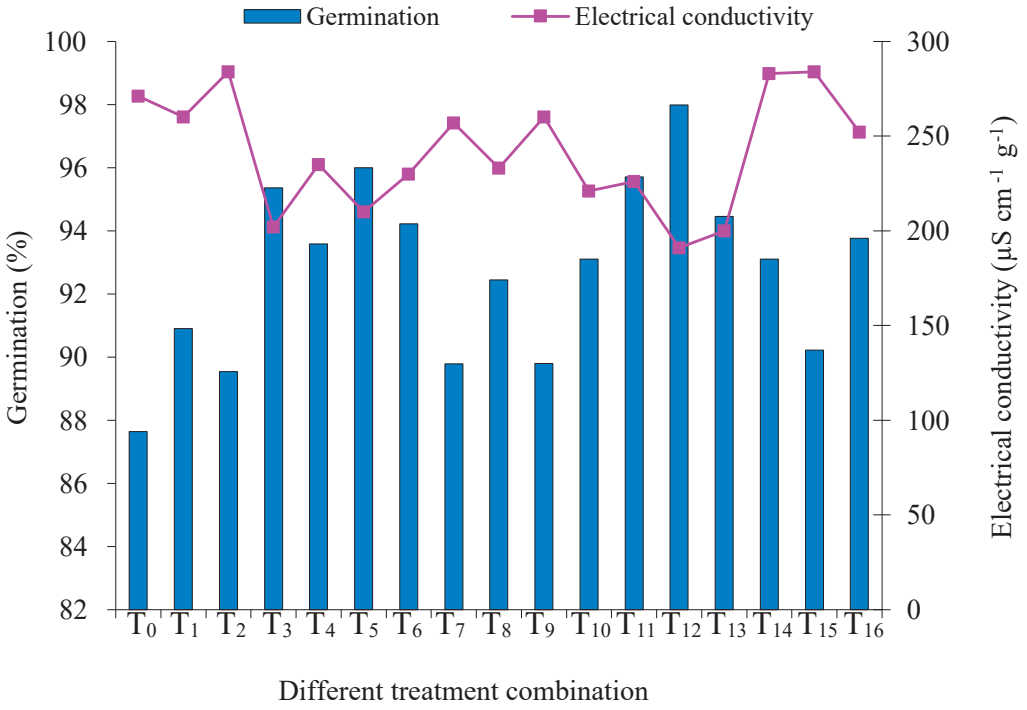


Figure 4. Seed quality of soybean harvested from different combination of foliar fertilization.

Where,

T_0=0-0-0-0-0; T_1=0-200-400-400-200; T_2=210-200-400-400-200; T_3=240-200-400-400-200; T_4=270-200-400-400-200; T_5=240-0-400-400-200; T_6=240-150-400-400-200; T_7=240-200-400-400-200; T_8=240-250-0-400-200; T_9=240-200-300-400-200; T_{10}=240-200-500-400-200; T_{11}=240-200-400-0-200; T_{12}=240-200-400-350-200; T_{13}=240-200-400-450-200; T_{14}=240-200-400-400-0; T_{15}=240-200-400-400-250; T_{16}=240-200-400-400-300 NPKSB mg L^{-1} water.

favorable effects on the metabolism of nucleic acids, protein, vitamins and other growth substances (Vlasynk *et al*. 1978). These effects are manifested in metabolites formed in plant tissues which have direct impact on growth development and may be reflected in distinct improvement in seed quality (Sawan *et al*. 1989).

Conclusion

Foliar fertilizer application directly improved the growth, yield and seed quality of soybean compared to control. The treatment combination of 240-200-400-350-200 mg L^{-1} NPKSB in water produced the highest seed yield and enhanced grain and seed quality by promoting the accumulation of various nutrients and metabolites in seed reserves. However, excessive nutrient application may cause leaf burn and reduce the yield and seed quality of soybean.

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