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SOLE AND COMBINED EFFECT OF SULPHUR AND BORON APPLICATION ON GROWTH AND YIELD OF NIGER (*GUIZOTIA ABYSSINICA*)

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ABSTRACT

A field experiment was carried out at Instructional Farm of Bidhan Chandra Krishi Viswavidyalaya, Jaguli, Nadia, West Bengal during winter (*rabi*) season of 2021-22 to find out sole and combined impact of sulphur and boron application on growth parameters, yield attributing components, yield and quality of Niger. The investigation was conducted with 12 treatments (T_1: control, T_2: 0.2% Solubor at branching stage, T_3: 0.2% Solubor at branching and flowering stage, T_4: 20 kg S/ha, T_5: 20 kg S/ha + 0.2% Solubor at branching stage, T_6: 20 kg S/ha + 0.2% Solubor at branching and flowering stage, T_7: 30 kg S/ha, T_8: 30 kg S/ha + 0.2% Solubor at branching stage, T_9: 30 kg S/ha + 0.2% Solubor at branching and flowering stage, T_{10}: 40 kg S/ha, T_{11}: 40 kg S/ha + 0.2% Solubor at branching stage and T_{12}: 40 kg S/ha + 0.2% Solubor at branching and flowering stage, each replicated three times using a randomised block design. The use of 40 kg S/ha along with 0.2% Solubor once at branching and another at flowering stage exhibited excellent performance in terms of all the growth parameters, yield attributes, yield (815 kg/ha), oil content (35.20%) and protein content (23.01%) of Niger, besides providing maximum B:C ratio (1.93). Combined application of sulphur in soil and foliar application of boron (single and double) was found to be superior than soil application of S or foliar application of boron alone, which augmented growth parameters, yield attributing components, yield and oil content of Niger significantly.
***Keywords**:* Boron, Niger, Oil content, Sulphur, Yield.

Introduction

Niger (*Guizotia abyssinica*), belongs to Asteraceae family, is an annual oilseed crop originated in Ethiopian highlands. In India, Niger is grown in marginal areas where it contributes a small but it is an important part of oilseed production mainly in tribal areas under rainfed condition. During 2021-22, Niger was grown in West Bengal covering 1120 ha with a total production of 586 tonnes; however, the productivity of this crop was too low (523 kg/ha) (Evaluation wing, Directorate of Agriculture, West Bengal, 2021-22). With respect to national area and production of Niger, West Bengal accounted only 0.43% and 0.07%, respectively. Hence, serious agronomic intervention is needed to boost Niger productivity in West Bengal, based on which Niger cultivated is expected to be increased in future. Out of various agronomic options, fertilizer application could play an important role in augmenting growth and productivity of Niger crop.

Till date, fertilization practice is mostly restricted to N, P and K-fertilizer application only. The use of secondary (Sulphur) and micronutrient (Boron) are still very meagre. Sulphur is the fourth most crucial nutritional element (after N, P and K) for crop production because of its role in enzymatic and metabolic processes. Additionally, it actively contributes to improved produce quality, oil and protein synthesis, seed yield, and plant growth in oilseed crops (Hussain *et al.*, 2011). Sulphur is the main constituent of various amino acids such as cystine, cysteine and methionine. Additionally, it makes crops more resilient to cold and drought, particularly oilseed crops (Patel and Shelke, 1995). Due to the availability of soluble fertilizers, foliar fertilization has become increasingly important in recent years. It is especially important in rainfed areas where climate conditions are changing. Boron is one of the micronutrients that is crucial for pollination and fertilization (Kundu *et al.,* 2023). If the supply of boron is reduced, it reduces oil production and degrades oil quality (Pahari *et al.,* 2024). Higher agricultural yields are the result of foliar application of boron, which improves plant physiological processes.

Hence, the present study was focused on deriving suitable combination of S and B application along with NPK fertilizers in order to augment growth, yield and seed quality of Niger in West Bengal condition.

Materials and Methods

A field trial was executed to investigate individual and combined impact of sulphur and boron on growth attributes, yield and quality of Niger during the winter (*rabi*) season of 2021-22 at Instructional Farm of Bidhan Chandra Krishi Viswavidyalaya (BCKV), Jaguli, Nadia, West Bengal, India. The farm is 9.75 meters above mean sea level and is situated at 22°93' N latitude and 88°53' E longitude. Maximum temperature varied between 35.31–22.46°C, while minimum temperature was within the range of 19.5–8.3°C during the experiment. At the time of experiment, maximum relative humidity was noted in between 98.00–90.71%, while minimum relative humidity was within the range of 78.85–34.4%. During experimental period total rainfall was recorded 193.5 mm. As a result, the Niger crop had favourable weather conditions and eventually showed good growth and development during the *rabi* season. Under medium land situation, the soil type was clay-loam (order Inceptisol) in texture and neutral in reaction (pH 7.08) and had medium organic C (0.61%), low available N (213.25 kg/ha), high P_2O_5 (31.39 kg/ha) and medium K_2O (138.47 kg/ha). Available sulphur (27.89 kg/ha) and available boron (0.49 mg/kg) was in medium and low range, respectively.

Randomized block design (RBD) was followed to organize the experiments (12 nos.), and there were three (03) replications. Treatments were as follows - T_1: control, T_2: 0.2% Solubor at branching stage, T_3: 0.2% Solubor at branching and flowering stage, T_4: 20 kg S/ha, T_5: 20 kg S/ha + 0.2% Solubor at branching stage, T_6: 20 kg S/ha + 0.2% Solubor at branching and flowering stage, T_7: 30 kg S/ha, T_8: 30 kg S/ha + 0.2% Solubor at branching stage, T_9: 30 kg S/ha + 0.2% Solubor at branching and flowering stage, T_{10}: 40 kg S/ha, T_{11}: 40 kg S/ha + 0.2% Solubor at branching stage and T_{12}: 40 kg S/ha + 0.2% Solubor at branching and flowering stage. Sulphur and boron were applied as GROMOR SULPHA MAX (Bentonite Sulphur 90%) and 0.2% Solubor (20% boron), respectively as per treatment details. All the plots received a uniform basal dose of 20 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha through urea, single super phosphate and muriate of potash, respectively. The Niger crop (var. BNS-10) was sown on 27.11.2021 with a spacing of 30 cm × 10 cm. Thinning was done at 25 DAS and two manual weeding were done at 21 and 42 DAS in all the plots. Three irrigations were administered at the pre-sowing, branching, and flowering periods. Harvesting was done on 22.03.2022 (115 DAS) when leaves and the whole plant became yellow by cutting with the help of sickle. After harvesting plants were dried under the sun in the field for 7 days. After that, seeds were separated by beating the capitula with sticks and further dried under the sun.

The growth attributes of Niger like plant height, leaf area index (LAI), dry matter production and crop growth rate (CGR) at various growth stages were noted. Five plants had been selected at random for the measurement of the plant height and production of dry matter. For measuring the accumulation of dry matter, a hot air oven was used to dry the samples at a temperature of 65°C for 12 hours until steady weight was gained. The area-weight relationship was used to get the total leaf area. Then, LAI was calculated by using the following formula (Watson, 1958).

$$\text{LAI} = \frac{\text{Leaf area per plant}\left(\text{cm}^2\right)}{\text{Land covered by individual plant}\left(\text{cm}^2\right)}$$

Crop growth rate (CGR) expresses the production of total dry matter of the crop community/unit land area/unit change of time (Watson 1952) and was calculated by the following formula and expressed in g/m^2/day.

$$\text{CRG} = \frac{W_2 - W_1}{t_2 - t_1}$$

Among yield attributing components, number of capitula/plant and number of seeds/capitulum were measured and finally, seed yield and stover yield were taken from each experimental plots and changed to kg/ha. Harvest Index (HI) was computed by –

$$\text{Hi} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

The seed quality parameters like protein content and oil content were estimated at the laboratory under Department of Agronomy, BCKV. Modified Kjeldahl techniques were used to determine the protein content (%) in the seed, by using the following formula:

$$\%\text{ of Nitrogen} = \frac{(\text{T} - \text{B}) \times 0.014 \times 0.1}{\text{Weight of the sample}} \times 100$$

Where, T = Titrated value, B = Blank value

$$\% \text{ of protein in seed} = \% \text{ of Nitrogen} \times 5.59$$

Oil extraction process was done with Soxhlet apparatus and oil content (%) was calculated using the following formula:

$$\text{Oil content}(\%) = \frac{W_2 - W_1}{W_g} \times 100$$

Where, Wg = Weight of sample; W_1 = Weight of empty glass vessel in gram; W_2 = Weight of glass vessel + oil extracted

The soil's available sulphur was taken out by using 0.15% $CaCl_2$ solution. The sulphur concentration was estimated by using turbidimetric method, as recommended by Berger and Truog (1939). The available proportion of boron in soil was extracted using $CaCl_2$-hot water and measured using UV-VIS spectrophotometer (VARIAN CARY-50). The economics of Niger production with respect to total cost of cultivation, gross return, net revenue and benefit: cost ratio (B:C) were calculated taking into consideration the market prices of inputs, outputs, and labour wages.

The data recorded during the investigation was analysed utilizing on-line OPSTAT software by following standard statistical procedures for randomized block design (Gomez and Gomez 1984).

Results and Discussion

Growth attributes

The use of sulphur in soil alone and in combination with foliar application of boron (single and double) have increased all the growth attributes of Niger throughout the entire cropping season. Plant height, LAI and dry matter production were gradually increased with the increase in individual and combined application of sulphur and boron in the study. The maximum plant height (75.00 cm) of Niger was observed at treatment T_{12} (*i.e.* application of 40 kg S/ha and foliar application 0.2% Solubor at branching and flowering stage) which was succeeded by treatment T_{11} (*i.e.* application of 40 kg S/ha and foliar application of 0.2% Solubor at branching stage) at harvest (Table 1). The plant height rose with the absorption of sulphur as it would speed up cell multiplication, elongation, and expansion throughout the crop's growth cycle (Ray *et al.,* 2015). Moreover, higher level of sulphur might have increased protein and carbohydrate metabolism that led to increase in shoot length of the crop by activating many enzymes (Ray *et al.,* 2016). The increase in plant height might be related to the adequate dosage of boron, which plays a significant role in several enzymatic and other biochemical activities (Indu and Singh, 2020). Leaf area index (LAI) of Niger increased progressively with the rise of the crop up to 90 DAS, then the LAI was decreased. At 90 DAS, the highest LAI value of 1.61 was recorded at treatment T_{12} (Table 1). Increasing plant height of Niger might also increase total number of leaves in plants, leading to more ground coverage. As the total leaf area per unit of ground area increased with increasing amount of sulphur and boron application, LAI also increased in Niger. Similar result was revealed at Dharwad, Karnataka (Gundagavi, 2017), where application of sulphur at 20 kg/ha + sulphur oxidizing bio-fertilizer showed significantly higher LAI (1.45) of Niger compared to control. The use of boron resulted in an increase in growth characteristics those might be owing to the rapid translocation of plant nutrients through foliar application to developing plant parts and production of more photosynthates, which in turn might have boosted a greater number of leaves and ultimately the LAI. The best result of dry matter production (398.13 g/m^2) was achieved at T_{12} at harvest, which was followed by treatment $T_{11.}$ The accumulation of dry matter was significantly impacted by the application of boron. When solubor was sprayed throughout the branching and flowering periods, more dry matter was produced; however, this had little effect on the initial growth of Niger. The results on dry matter production were also corroborated with the data recorded by Sarkar and Saha (2005). Crop growth rate (CGR) of Niger at different growth stages is depicted in the Figure 1. The various nutrient-based treatments had a considerable impact on the CGR of Niger, the maximum value of CGR during 31-60 DAS, 61-90 DAS and 91 DAS-harvest was obtained at treatment T_{12} and it was succeeded by treatment $T_{11.}$ Findings of Sarkar and Saha (2005) revealed that boron application twice at branching and blooming stages were superior to those of control situation and borax spraying only at branching stages.

Yield components and yield

Application of 40 kg S/ha and foliar application of 0.2% Solubor at branching and flowering stage (T_{12}) produced the greatest seed yield (815 kg/ha) which was 378 kg higher than the control (T_1) and 8% greater over treatment T_{11} due to significant improvement in number of capitula/plant (56) and number of seeds/capitulum (33) in T_{12} treated plot. According to the above findings, use of sulphur in combination with boron had a beneficial effect on the number of capitula/plants, and similarly higher sulphur dosages had a significant impact on the number of capitula/ plants. A rise in the number of capitula/plant with application of sulphur and boron might be the result of boron's impact in improving fertility and translocating photosynthates (Rana *et al.,* 2005). The use of sulphur and boron may cause an increase in the quantity of seeds/capitulum due to their pivotal role in amino acid and protein synthesis, fertility improvement and seed filling (Kar *et al.,* 2013). All of these resulted in an increase in seed set and photosynthetic translocation to the sink, which boosted seed yield of Niger. The treatment T_{12} also produced maximum stover yield of 3910.25 kg/ha that was statistically comparable with treatment T_{11} and T_{10}, representing 1319.51 kg/ha stover higher than control treatment (Figure 2). The use of sulphur might have increased stover yield because it improved metabolism and increased the effectiveness of other nutrients. The maximum value of HI was calculated in the treatment T_{12} (17.25%) (Figure 3).

The significant positive correlation (0.988**) (Table 3) between production of dry matter at harvest and seed yield and also between the plant height at harvest and seed yield (0.940**) indicated that higher uptake of nutrients led to higher plant height and consequently LAI and also the accumulation of dry matter and subsequent translocation of photosynthates to seed, owing to higher seed yield of Niger in the study. The correlation study also revealed that correlation between plant dry matter production at harvest and number of capitula/plant is highly significant (0.916**), that also claimed the significant contribution of foliar treatment of boron and soil application of sulphur towards better production of vegetative growth parameters and followed by greater quantitative values of yield components and finally economic yield. The improvement in yield caused by sulphur fertilization was clear since it enhanced the overall nutritional environment of the rhizosphere as well as the plant system. Similar trend in yield improvement was found in another study, where seed and stover yield of Niger were recorded the highest with the application of maximum amount of the sulphur and boron @ 45 and 1.5 kg/ha, respectively; that was significantly greater over the other doses of sulphur *viz.,* 0, 15, 30 kg/ha and boron *viz.,* 0, 0.5, 1.0 kg/ha, in red and lateritic soils of West Bengal (Chatterjee *et al.,* 2019).

Seed quality parameters

In the research, basal application of sulphur @ 20 kg/ha (T_4) and @ 30 kg/ha (T_7) enhanced Niger oil content by 12.78% and 16.67%, respectively when compared to control treatment (T_1), but oil content was increased significantly 19.37% under use of sulphur @ 40 kg/ha (T_{10}) over control. According to Mamatha *et al.* (1994), oil content of Niger was increased with increasing sulphur application. The use of sulphur may have promoted the production of CoA and lipoic acid, which resulted an enhanced oil content (Mathew and George, 2013). Singh *et al.* (2000) also proved that oil content and production of Niger increased with subsequent sulphur treatment up to 45 kg/ha in contrast to control situation at Ranchi during late *kharif* season of 1997 on acidic soils of Bihar plateau. However, treatment T_{12} recorded the highest oil content (35.20%) which is 26.76% higher than control (T_1) (Table 2). Oil content rose with the increase in foliar application of boron, while an insufficient supply of boron hindered oil output and deteriorated oil quality (Praveen *et al.*, 2020). Boron is also claimed as equally effective in increasing oil content of oilseed crop along with application of sulphur (Indu and Singh, 2020). The improved oil yield of Niger was obtained from treatment T_{12} (286.88 kg/ha) where the application of sulphur @ 40 kg/ha along with foliar spray of 0.2% Solubor at branching and flowering increased oil yield over no sulphur and boron application to the tune of 165.53 kg/ha. Combine application of sulphur and boron improved the yield of crop, and thereby promoted the oil yield of Niger (Figure 4).

Protein content of Niger varied between 15.34% to 23.01% (Table 2). Protein content of Niger was greatly impacted by use of sulphur. When sulphur was applied @ 20 kg/ha, the protein content was increased 17.34%, and when applied as @ 30 kg/ha, the protein content was increased 41.32%, but protein content was increased significantly 46.41% under application of sulphur @ 40 kg/ha over control treatment (T_1). Application of micronutrient boron with sulphur further enhanced the protein content. However, the highest protein content 23.01% was obtained from the treatment T_{12}. Application of micronutrient boron in combinations with sulphur further increased the protein yield. Significantly higher protein yield (187.53kg/ha) was obtained with the treatment T_{12} which was superior to all other treatments (Figure 4). As sulphur is an important component of the amino acids cystine, cysteine, and methionine, its application improved the protein content of Niger seed; this might be because higher nitrogen content in seed increased protein content.

Residual status of Sulphur and boron in post-harvest soil

Different doses of sulphur along with micronutrient boron exerted significant influence on residual soil available sulphur and boron. The treatment T_{12} recorded the maximum value of sulphur and boron 34.25 kg/ha and 0.65 mg/kg of soil, respectively and treatment T_1 recorded minimum value of sulphur and boron 24.36 kg/ha and 0.48 mg/kg of soil, respectively (Table 2). So, the results showed that, with the increasing application rate of sulphur and boron, availability of these nutrients in soil after harvest had also increased due to the synergistic effect between them.

Economic analysis

The common expenditure incurred for all the experimental units was Rs. 20068/ha. Treatment T_{12} reported the maximum value of gross monetary return (Rs. 51880/ha), net monetary return (Rs. 24993/ha) and B:C ratio (1.93) as well (Table 2), due to maximum increase in biological yield.

Considering the findings as summarized above, it might be said that the use of 40 kg S/ha and foliar treatment of 0.2% Solubor at branching and flowering stage, besides NPK-fertilization can be considered as an effective treatment for achieving increased seed and oil output and also maximum net income of Niger cultivation for Gangetic alluvial zone of West Bengal.

Table 1: Impact of different levels of Sulphur and boron on growth parameters, yield attributes and yield of Niger during *rabi* season of 2021-22

Treatments	Plant height (cm) at harvest	LAI at 90 DAS	Dry matter accumulation (g/m^2) at harvest	Number of branches /plant	Number of capitula /plant	Number of seeds/ capitulum	1000 seed weight (g)	Seed yield (kg/ha)
T_1: Control	66.67	1.00	205.87	6	44	27	3.18	437
T_2: 0.2% Solubor at branching stage	67.00	1.07	230.66	6	47	28	3.19	510
T_3: 0.2% Solubor at branching and flowering stage	67.33	1.08	248.54	6	48	29	3.19	550
T_4: 20 kg S/ha	67.67	1.10	255.82	7	50	29	3.19	560
T_5: 20 kg S /ha + 0.2% Solubor at branching stage	68.00	1.14	281.85	7	51	30	3.19	590
T_6: 20 kg S/ha+ 0.2% Solubor at branching and flowering stage	68.67	1.19	293.01	7	52	31	3.20	617
T_7: 30 kg S/ha	69.00	1.24	308.98	8	52	31	3.19	615
T_8: 30 kg S/ha + 0.2% Solubor at branching stage	69.33	1.25	328.36	8	53	32	3.19	674
T_9: 30 kg S/ha + 0.2% Solubor at branching and flowering stage	70.67	1.30	338.51	8	54	32	3.20	697
T_{10}: 40 kg S/ha	72.33	1.44	355.90	8	55	32	3.19	690
T_{11}: 40 kg S/ha + 0.2% Solubor at branching stage	73.33	1.50	375.89	8	56	32	3.20	750
T_{12}: 40 kg S/ha + 0.2% Solubor at branching and flowering stage	75.00	1.61	398.13	9	56	33	3.20	815
SEm±	1.49	0.03	2.18	0.49	1.51	0.95	0.01	12.44
CD (P = 0.05)	4.28	0.08	6.26	1.40	4.35	2.73	NS	35.72

DAS= Days after sowing; NS= Non-significant

Table 2: Impact of different levels of Sulphur and boron on quality of seed, residual boron and sulphur status in post-harvest soil and economics of Niger during *rabi* season of 2021-22.

Treatments	Oil content (%)	Protein content (%)	Soil available S (kg/ha)	Soil available B (mg/kg)	Gross return (Rs./ha)	Net income (Rs./ha)	B : C ratio
T_1: Control	27.77	15.34	24.36	0.48	28811	8743	1.44
T_2: 0.2% Solubor at branching stage	28.08	15.42	25.51	0.51	33356	11984	1.56
T_3: 0.2% Solubor at branching and flowering stage	29.76	15.97	26.32	0.54	35877	13201	1.58
T_4: 20 kg S/ha	31.32	18.00	28.67	0.52	36516	14014	1.62
T_5: 20 kg S /ha + 0.2% Solubor at branching stage	31.61	18.55	29.34	0.55	38664	14858	1.62
T_6: 20 kg S/ha+ 0.2% Solubor at branching and flowering stage	32.07	19.25	30.09	0.58	40467	15357	1.61
T_7: 30 kg S/ha	32.40	21.68	30.88	0.54	40656	17265	1.74
T_8: 30 kg S/ha + 0.2% Solubor at branching stage	33.40	22.15	31.54	0.58	43946	19251	1.78
T_9: 30 kg S/ha + 0.2% Solubor at branching and flowering stage	34.57	22.62	32.14	0.60	45337	19818	1.78
T_{10}: 40 kg S/ha	33.15	22.46	32.97	0.57	45288	21009	1.87
T_{11}: 40 kg S/ha + 0.2% Solubor at branching stage	34.47	22.85	33.67	0.62	47959	22376	1.87
T_{12}: 40 kg S/ha + 0.2% Solubor at branching and flowering stage	35.20	23.01	34.25	0.65	51880	24993	1.93
SEm±	0.78	0.17	0.67	0.03	196.95	98.47	0.03
CD (P = 0.05)	2.23	0.49	1.93	0.09	565.43	282.72	0.09

DAS= Days after sowing

Table 3: Pearson's correlation matrix showing pair-wise association of different growth attributes, yield parameters and yield of Niger

	Seed yield (kg/ha)	Stover yield (kg/ha)	Plant height at harvest (cm)	Dry matter accumulation (g/m^2) at harvest	Number of branches /plant	Number of Capitula/ plant	Number of seeds/ capitulum	1000 seed weight
Seed yield (kg/ha)	1.000	0.932**	0.940**	0.988**	0.960**	0.941**	0.965**	0.781**
Stover yield (kg/ha)	0.932**	1.000	0.933**	0.968**	0.951**	0.843**	0.938**	0.577*
Plant height at harvest (cm)	0.940**	0.933**	1.000	0.951**	0.888**	0.920**	0.873**	0.665*
Dry matter accumulation (g/m^2) at harvest	0.988**	0.968**	0.951**	1.000	0.981**	0.916**	0.978**	0.718*
Number of branches/plant	0.960**	0.951**	0.888**	0.981**	1.000	0.862**	0.995**	0.704*
Number of Capitula/plant	0.941**	0.843**	0.920**	0.916**	0.862**	1.000	0.860**	0.700*
Number of seeds/capitulum	0.965**	0.938**	0.873**	0.978**	0.995**	0.860**	1.000	0.731*
1000 seed weight	0.781**	0.577*	0.665*	0.718*	0.704*	0.700*	0.731*	1.000

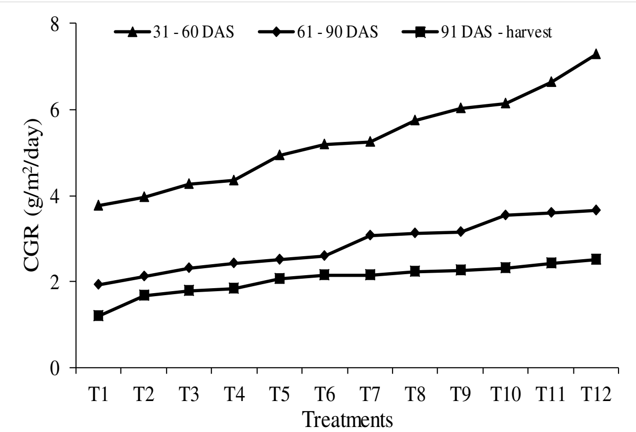

Fig. 1: Impact of different levels sulphur and boron on CGR of Niger during *rabi* season of 2021-22

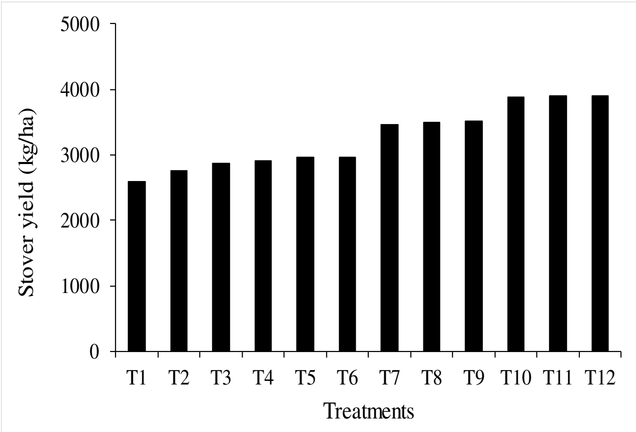

Fig. 2: Impact of different levels sulphur and boron on stover yield of Niger during *rabi* season of 2021-22

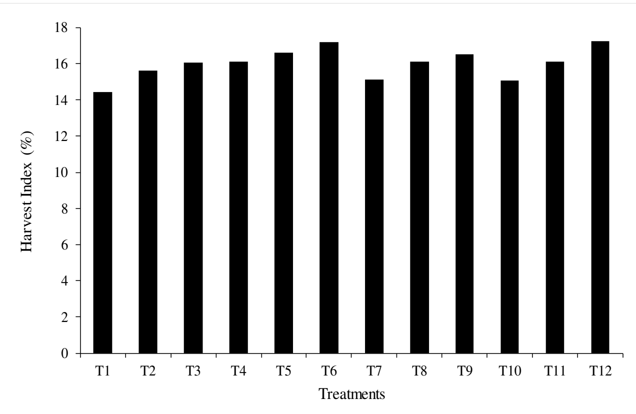

Fig. 3: Impact of different levels sulphur and boron on harvest index of Niger during *rabi* season of 2021-22

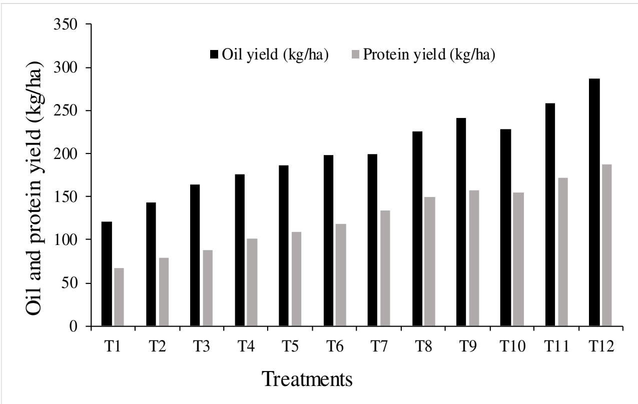

Fig. 4: Impact of different levels sulphur and boron on oil yield (kg/ha) and protein yield (kg/ha) of Niger during *rabi* season of 2021-22.

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