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Seed Yield and Nutrient Uptake of Sunflower (*Helianthus annuus* L.) as Influenced by Different Levels of Boron and Potassium in Sandy Loam Soil

P. Jyothi[1], T. Anjaiah[1], I.Y.L.N. Murthy[2]*, Rajeshwar Naik[1] and S.A. Hussain[1]

[1]Department of Soil Science and Agricultural Chemistry, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad- 500 030, Telangana, India
[2]ICAR-Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad- 500 030, Telangana, India

**Corresponding author*

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A B S T R A C T

A field experiment was laid out in factorial randomized block design with 16 treatment combination comprising of four levels of boron and four levels of potassium *viz*., (B_0K_0), (B_0K_{15}), (B_0K_{30}), (B_0K_{60}), ($B_{0.5}K_0$), ($B_{0.5}K_{15}$), ($B_{0.5}K_{30}$), ($B_{0.5}K_{60}$), (B_1K_0), (B_1K_{15}), (B_1K_{30}), (B_1K_{60}), ($B_{1.5}K_0$), ($B_{1.5}K_{15}$), ($B_{1.5}K_{30}$), ($B_{1.5}K_{60}$) to investigate the influence of application of different levels of boron and potassium with recommended dose of N and P fertilizers on sunflower (*Helianthus annuus* L.) hybrid,GK-2002 to find out the nutrient (Nitrogen, phosphorus, potassium and boron) uptake and optimum dosage of boron and potassium to increase the sunflower seed yield. In the present investigation, sunflower shoot uptake of major nutrients like N and P were significantly influenced by the application of B and K at 60 and 90 DAS. Nutrient uptake by sunflower seed increased with increasing levels of boron and potassium application. Seed nutrient uptake of N, P, K and B were 43.83, 11.85, 13.65 kg ha^{-1} and 33.24 kg ha^{-1}, respectively with $B_{1.5}$ K_{60}, which is at par with B_1K_{30} treatment. Maximum seed yield was obtained with $B_{1.5}K_{60}$ treatment fallowed by $B_{1.5}K_{30}$, B_1K_{30} and B_1K_{60}. Boron and potassium levels and B x K interaction were found significant in both shoot and seed. Even though highest seed yield with $B_{1.5}$ K_{60} treatment was recorded, B_1K_{30} treatment showed was economically beneficial.

Introduction

Sunflower (*Helianthus annuus* L) is one of the important edible oilseed crops cultivated in India in various soil types. Soil fertility in terms of nutrient sufficiency and deficiency for all types of Indian soils is well documented (Sahrawat*et al* 2007, Pathak 2010, Shukla *et al* 2014). Sunflower growing soils of Telangana State are found to be deficient in important nutrients viz. nitrogen, potassium, sulphur, zinc and boron (Rego*et al.*, 2007, Murthy *et al.*, 2009, Bhupal Raj *et al.*, 2009) which are highly essential to attain higher seed yield and oil quality. Sunflower is one of the most sensitive crops to B deficiency. Boron deficiency symptoms in sunflower become evident on leaves, stems, reproductive parts, dry matter, yield components and seed yield. Asad*et al.*, (2003) reported that B requirement of sunflower during reproductive growth is higher than during vegetative growth. At flowering, B deficiency can affect pollen viability and abortion of stamens and pistils which contribute to poor seed set due to malformed capitulums and consequently low seed yield (Chatterjee and Nautiyal, 2000). Potassium plays key role in increasing crop yield and improving the quality of product (Soleimanzadeh *et al.,* 2010). Application of potassium plays a remarkable role in boosting up production (Blamey *et al.,* 1979). The effect of potassium application on sunflower plant growth, yield and quality was reported by some investigators, who found that increasing potassium level led to a significant increase in plant height (Sirbu and Ailincai, 1992), number of leaves, leaf area and head diameter (Lewis *et al.,* 1991).

Boron and potassium have overlapping roles to play in plant physiology and hence, are synergistic. Like potassium, boron is also involved in some aspects of flowering and fruiting processes, pollen germination, cell division, nitrogen metabolism, carbohydrate metabolism, active salt absorption, hormone movement and action, water metabolism and the water relations in plants. They both serve in acting as a buffer and are necessary in the maintenance of conducting tissues and to exert a regulatory effect on other elements. It has been shown that an optimal level of boron increases potassium permeability in the cell membrane (Ujwala, 2011). Keeping this in view a field study was conducted in sandy loam soil to assess the seed yield and nutrient uptake of sunflower as influenced by different levels of boron and potassium.

Materials and Methods

Afield experiment was conducted on sandy loam soil at Agricultural College farm, Rajendranagar, Hyderabad during *Rabi*, 2016. The experimental field was moderately alkaline in soil reaction (pH 8.24), non-saline, and low in organic carbon (0.42%) content. The chemical properties of soil showed that it was medium in nitrogen (294 kg ha^{-1}), phosphorus (30 kg ha^{-1}) and potassium (204.2 kg ha^{-1}) and deficient in available soil boron i.e. 0.4 mg kg^{-1}.

The experiment was laid out in factorial randomized block design with 16 treatment combination comprising of four levels of boron and four levels of potassium *viz*., T_1(B_0 K_0), T_2 (B_0 K_{15}), T_3 (B_0 K_{30}), T_4 (B_0 K_{60}), T_5 ($B_{0.5}$ K_0), T_6 ($B_{0.5}K_{15}$), T_7 ($B_{0.5}$ K_{30}), T_8 ($B_{0.5}K_{60}$), T_9 (B_1 K_0), T_{10} (B_1 K_{15}), T_{11} (B_1K_{30}), T_{12} (B_1K_{60}), T_{13} ($B_{1.5}K_0$), T_{14} ($B_{1.5}$ K_{15}), T_{15} ($B_{1.5}$ K_{30}), T_{16} ($B_{1.5}$ K_{60}) with recommended dose of N and P fertilizers on sunflower hybrid GK-2002. All the need based crop management practices were followed as in vogue. Dry matter accumulation was recorded at 60 DAS and 90 DAS by randomly tagging five plants from each plot which were cut from the base at each stage and separated into leaf + stem and head. They were shade dried and later oven dried at 65^{o}C till constant weight was obtained. The oven dried weight of leaf, stem and head were recorded and pooled. Plant samples were digested with di-acid mixture of 9:4 (HNO_3:$HClO_4$) (Piper, 1966). Nitrogen content in plant samples were estimated by modified microkjeldahl method (Piper, 1966). Phosphorus content was determined by Vanado–molybdophosphoric yellow colour method using Spectrophotometer at 420 nm. And potassium content was determined with ELICO – Flame Photometer (Piper, 1966).Boron content was determined by dry ashing in muffle furnace at 550ºC for 2-3 hours and subsequent extraction with 0.1N HCl (Gaines and Mitchell, 1979). Nutrient uptake was computed by multiplying the respective nutrient content with corresponding drymatter/seed yield and expressed in kg ha^{-1}. At harvest sunflower seed yield was recorded.

Results and Discussion

Effect of boron and potassium levels on drymatter[sunflower shoot (leaf + stem and head)]yield, uptake of nitrogen, phosphorus, potassium and boron at 60 and 90 days after sowing is presented in table 1 and discussed below.

Dry matter

At 60 DAS, boron levels had significant effect on drymatter. Among all the treatments highest dry matter production was recorded in $B_{1.5}$ kg ha^{-1} + K_{60} kg ha^{-1}. Significantly lowest dry matter production was recorded in control. Whereas drymatter production was significantly highest at $B_{1.5}K_{60}$ as compared to control. The results revealed that dry matter production increased with increasing levels of boron and potassium. The B x K interaction effects were also found significant on drymatter production. The synergistic interaction between B and K might have increased dry matter yield significantly.

At 90 DAS, also similar trends were observed regarding shoot yield. Boron and potassium had significant effect on shoot yield. There was progressive increase in shoot yield from control to $B_{1.5}$ K_{60}. However, it is statistically at par with B_1K_{30}, B_1K_{60} and $B_{1.5}$ K_{30}. Increase in drymatter yield could be due to activation of some of the fundamental processes with B nutrient such as cell elongation and division as well as nucleic acid metabolism. (Shelp, 1993 and Ruiz *et al.*, 1998)

Tiwari *et al.*, (2012) reported that application of K up to 60 kg K_2O ha^{-1} also significantly increased shoot yields of mustard. Karthikeyan *et al.*, (2008) noticed that significant increase in drymatter with the increasing levels of applied boron in mustard crop. Duyingqiong *et al.*, (2002) reported that B fertilizer significantly enhanced photosynthetic activity of leaves, which consequently resulted in more accumulation of dry matter in peanut (*Arachis hypogeal* L.). Ahmed *et al.*, (2011) also observed that dry matter yield increased significantly with B up to 2.0 kg ha^{-1}.

Nitrogen uptake

The results showed that boron and potassium levels significantly influenced nitrogen uptake by sunflower plant (Table 1). At 60 DAS, uptake of nitrogen varied from 33.24 kg ha^{-1} to 71.39 kg ha^{-1}. Soil application of boron had significant effect on nitrogen and maximum N uptake was recorded with 1.5 kg B ha^{-1} as compared to 0 kg B ha^{-1}. However, it was statistically at par with 1 kg B ha^{-1}.Potassium application also had significant effect on nitrogen uptake and there was gradual increase in nitrogen uptake with increasing levels of potassium. The highest nitrogen uptake was recorded in treatment $B_{1.5}K_{60}$ however it is statistically on par with B_1K_{30}, B_1K_{60} and $B_{1.5}K_{30}$ treatments.

Similar trend were noticed in N uptake at 90 DAS. The highest nitrogen uptake recorded with treatment $B_{1.5}$ K_{60} which were on par with B_1K_{30}, B_1K_{60} and $B_{1.5}K_{30}$ treatments, however it is significant over control (Table 1).

Phosphorus uptake

At 60 DAS, phosphorus uptake of shoot varied from 3.17 kg ha^{-1} at control to 9.54 kg ha^{-1} treatment. Soil application of boron had significant effect on phosphorus uptake and maximum P uptake was recorded with 1.5 kg B ha^{-1} as compared to 0 kg B ha^{-1} (Table 1). However, it was statistically at par with 1 kg B ha^{-1}. Potassium application also had significant effect on phosphorus uptake and there was a progressive increase in phosphorus uptake with increasing levels of potassium.

The highest phosphorus uptake was recorded in treatment $B_{1.5}K_{60}$, however it is statistically on par with B_1K_{60}, $B_{1.5}K_{30}$ treatments. Similar trends were noticed in shoot P uptake at 90 DAS. The highest phosphorus uptake was recorded with treatment $B_{1.5}K_{60}$which were on par with B_1K_{30}, B_1K_{60} and $B_{1.5}K_{30}$treatments but significant over control (Table 1).

Potassium uptake

Potassium uptake at 60 DAS by shoot varied from 43.47 kg ha^{-1} to 122.41 kg ha^{-1}. Soil application of boron had significant effect on potassium uptake and maximum mean K uptake was recorded with 1.5 kg B ha^{-1} as compared to 0 kg B ha^{-1} (Table 1).

However, it was statistically at par with 1 kg B ha^{-1}.Potassium application also had significant effect on shoot potassium uptake and there was a progressive increase in potassium uptake with increasing levels of potassium. The highest potassium uptake was recorded in treatment $B_{1.5}K_{60,}$ however it is statistically on par with $B_{1.5}K_{30}$ treatment.

Similar trend were noticed in shoot K uptake at 90 DAS. The highest potassium uptake recorded with treatment 1.5 kg B ha^{-1} + 60 kg K ha^{-1} which was on par with B_1K_{30}, B_1K_{60} and $B_{1.5}K_{30}$ treatments but significant over control. Brar *et al.,* (2010) reported that potassium uptake by straw was more as compared to the seeds. This was due to high content of K in straw than the grains. K uptake increased with the increase in levels of applied potassium.

Application of 90 kg K_2O ha^{-1} increased the K uptake from 22.1 to 34.4 kg ha^{-1} in seeds and from 102.4 to 154.2 kg ha^{-1} in straw over no K application. Bestas and Celik (2013) reported that in sunflower the highest potassium uptake was found at 4.0 and 8.0 mg B kg^{-1} doses.

Boron uptake

Boron uptake by sunflower was significantly influenced by boron and potassium levels.At 60 DAS, boron uptake by sunflower varied from 65.21 g ha^{-1} to 286.05 g ha$^{-1.}$ Soil application of boron had significant effect on boron uptake and maximum B uptake was recorded with 1.5 kg B ha^{-1} as compared to 0 kg B ha^{-1}. However, it was statistically at par with 1 kg B ha^{-1} (Table 1). Potassium application also had significant effect on boron uptake and there was a progressive increase in mean B uptake with increasing levels of potassium. The highest B uptake was recorded in treatment $B_{1.5}K_{60}$ however it is statistically on par with $B_{1.0}K_{30}$ treatment.

Similar trend was noticed in shoot B uptake at 90 DAS. The highest boron uptake recorded with treatment 1.5 kg B kg ha^{-1} + 60 kg K kg ha^{-1} which were on par with B_1K_{60} and $B_{1.5}K_{30}$ treatments, however it was significant over control (Table 1).

Seed yield

Sunflower seed yield among the various B and K treatments ranged from 952.8 to 1430 kg ha^{-1} (Table 2). Soil application of boron had significant effect on seed yield and maximum yield was recorded with 1.5 kg B ha^{-1} as compared to control. However, it was statistically at par with 1 kg B ha^{-1} (Table 2).

Potassium application also had significant effect on yield and there was progressive increase in seed yield from 969.4 to 1334 kg ha^{-1} with increasing levels of potassium i.e. 0 to 60 kg ha^{-1}. The highest seed yield was recorded in treatment $B_{1.5}K_{60}$, however it is statistically on par with B_1K_{30}, B_1K_{60} and $B_{1.5}$ K_{30} treatments. Seed yield was also significantly influenced by B x K interaction (Table 2).

Adequate supply of recommended dose of fertilizers along with boron and potassium application had positively reflected in attaining higher seed yield. Boron known to play major role in improving the head diameter and viability, germination and growth of pollen tubes which in turn might have resulted in more filled seeds. Seed yield increased through potassium application may be due to its key role in increasing crop yield and improving the quality of product and hence, the transport of nutrients is essential to metabolism in active areas. Similar results were obtained by Ahmed *et al.*, (2001) who found that head diameter, weight of thousand seed and seed yield increased with increasing potassium application rates from 0 to 150 kg ha^{-1}.

Renukadevi *et al.*, (2002) studied the effect of different levels of boron (0.5, 1.0, 1.5 and 2.0 kg ha^{-1}) as soil application and two levels of foliar spray (0.2% and 0.3%).The highest seed yield was recorded for the soil application of B @2.0 kg ha^{-1}. The yield increase in sunflower was 3.6 to 15.8 per cent and 7.2 to 18.9 per cent over the control for both seed and stalk, respectively.

Nitrogen uptake

At harvest seed uptake of nitrogen was significantly affected by boron and potassium levels. Uptake of seed nitrogen varied from 28.81 kg ha^{-1} to 43.83 kg ha^{-1} with the treatments $B_{1.5}K_{60}$ and B_0K_0 (Table 2). B x K interactions showed significant influence on nitrogen uptake. Brar *et al.*, (2010) reported that the significant increase in N uptake by sunflower seeds was noticed with the application of increased levels of potassium application and the highest crop uptake was noticed at 90 kg K_2O ha^{-1}. The increase in shoot N uptake was mainly due to increase in shoot yield.

Phosphorus uptake

At harvest seed uptake of phosphorus was significantly affected by boron and potassium levels. Uptake of seed phosphorus varied from 8.37 kg ha^{-1} to 13.73 kg ha^{-1} with the treatments of control and 1.5 kg B ha^{-1} + 30 kg K ha^{-1}. B x K interactions showed significant influence on phosphorus uptake (Table 2). Ramulu *et al.*, (2011) reported that phosphorus uptake significantly affected by the different levels boron. Brar *et al.*, (2010) reported that phosphorus uptake both by seeds and straw increased with the application of both phosphorus and potassium.

Potassium uptake

At harvest seed uptake of potassium was significantly influenced by boron and potassium levels. Uptake of seed potassium varied from 8.09 kg ha^{-1} to 3.90 kg ha^{-1} with the treatments of 1.5 B kg ha^{-1} + 30 K kg ha^{-1} and control. B x K interactions also significantly influenced the potassium uptake by sunflower (Table 2).

Boron uptake

At harvest seed uptake of boron was significantly influenced by boron and potassium levels. Uptake of seed boron varied from 8.56 kg ha^{-1} to 32.63 kg ha^{-1} with the treatments of 1.5 kg B ha^{-1} + 30 kg K ha^{-1} and control. B x K interaction was also significantly influenced potassium uptake (Table 2). Siddiqui *et al.*, (2009) reported that the soil incorporation of 15 kg Zn ha^{-1} and 1.5 kg B ha^{-1} doses recorded B uptake (157.53 g ha^{-1}). Unfertilized plots recorded lower nutrient uptake values.

Thus, in the present investigation, the increasing level of B and K, increased the drymatter production at 60 and 90 DAS.

Table.1 Effect of boron and potassium levels on drymatter yield and uptake of nitrogen, phosphorus, potassium and boron by sunflower (cv. GK 2002) shoot at 60 and 90 days

	60 days					90 days				
Drymatter yield (kg/ha)										
Potassium ($kg\ ha^{-1}$)	Boron ($kg\ ha^{-1}$)				Mean	Boron ($kg\ ha^{-1}$)				Mean
	0	0.5	1	1.5		0	0.5	1	1.5	
0	1504.33	1514.00	1520.67	1526.00	1516.25	2204.3	2214.0	2220.7	2226.0	2216.3
15	2046.96	2320.00	2794.67	2851.00	2503.16	3067.0	3340.0	3814.7	3871.0	3523.2
30	2343.67	2576.33	3131.33	3157.00	2802.08	3443.7	3676.3	4231.3	4200.0	3887.8
60	2456.33	2814.00	3146.00	3188.00	2901.08	3556.3	3914.0	4246.0	4275.0	3997.8
Mean	2087.82	2306.08	2648.17	2680.50		3067.8	3286.1	3628.2	3643.0	
		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		
Boron levels		42.8		123.7		46.5		134.5		
Potassium levels		42.8		123.7		46.5		134.5		
Interaction (B x K)		85.6		247.4		93.2		269.1		
Nitrogen uptake (kg/ha)										
0	33.24	33.59	33.40	33.86	33.52	27.23	27.45	27.61	27.68	27.49
15	44.96	51.67	62.29	63.55	55.62	38.03	41.30	47.42	47.87	43.66
30	52.00	57.41	69.80	70.71	62.48	42.69	46.19	53.29	53.83	49.00
60	54.69	61.60	70.86	71.39	64.64	44.11	48.93	53.64	53.91	50.15
Mean	46.22	51.07	59.09	59.88		38.01	40.97	45.49	45.82	
		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		
Boron levels		1.14		3.3		0.69		1.99		
Potassium levels		1.14		3.3		0.69		1.99		
Interaction (B x K)		2.28		6.6		1.38		3.99		
Phosphorus uptake (kg/ha)										
0	3.17	3.42	3.49	3.64	3.43	1.56	1.74	2.06	2.06	1.85
15	4.97	5.78	7.27	7.42	6.36	3.22	4.18	4.55	4.85	4.20
30	6.11	7.24	8.64	9.13	7.78	4.63	4.61	6.09	6.15	5.37
60	6.96	8.08	9.21	9.54	8.45	4.82	5.84	6.29	6.37	5.83
Mean	5.30	6.13	7.15	7.43		3.56	4.09	4.75	4.86	
		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		
Boron levels		0.21		0.63		0.27		0.77		
Potassium levels		0.21		0.63		0.27		0.77		
Interaction (B x K)		0.43		NS		0.53		NS		
Potassium uptake (kg/ha)										
0	43.47	44.21	45.01	45.62	44.58	48.79	24.40	50.56	51.20	41.25
15	67.28	80.61	101.25	104.92	88.51	76.99	46.00	103.32	107.48	75.44
30	80.03	93.79	118.57	120.70	103.27	91.07	60.54	132.37	135.81	94.66
60	86.57	104.70	119.83	122.41	108.38	95.97	77.98	135.96	138.03	103.31
Mean	69.34	80.83	96.16	98.41		78.21	52.23	105.55	108.13	
		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		
Boron levels		1.69		4.9		2.3		6.65		
Potassium levels		1.69		4.9		2.3		6.65		
Interaction (B x K)		3.39		9.81		4.6		13.3		
Boron uptake (g/ha)										
0	65.21	70.44	76.93	92.81	76.35	35.65	39.59	42.44	46.89	41.14
15	105.45	144.91	216.51	249.19	179.01	53.16	68.75	85.61	96.36	75.97
30	135.71	202.25	275.65	282.44	224.01	62.22	82.62	112.88	115.85	93.39
60	150.81	221.09	282.46	286.05	235.10	66.84	89.54	114.20	115.51	96.52
Mean	114.29	159.67	212.89	227.62		54.47	70.13	88.78	93.65	
		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		
Boron levels		7.73		22.34		2		5.79		
Potassium levels		7.73		22.34		2		5.79		
Interaction (B x K)		15.47		44.68		4.01		11.59		

Table.2 Effect of boron and potassium levels on seed yield and uptake of nitrogen, phosphorus, potassium and boron by sunflower (cv. GK 2002) seed

Seed yield (kg/ha)					
Potassium(kg ha^{-1})	Boron (kg ha^{-1})				Mean
	0	0.5	1	1.5	
0	952.8	961.3	975.3	988.0	969.4
15	1025.3	1114.7	1272.0	1290.7	1175.7
30	1156.0	1226.0	1410.7	1419.3	1303.0
60	1187.0	1305.7	1416.0	1430.0	1334.7
Mean	1080.3	1151.9	1268.5	1285.1	
		SEm±		CD (P=0.05)	
Boron levels		16.2		46.8	
Potassium levels		16.2		46.8	
Interaction (B x K)		32.4		93.7	
Nitrogen uptake (kg/ha)					
0	28.81	29.09	29.49	29.87	29.31
15	31.30	34.11	38.92	39.50	35.96
30	35.27	37.50	43.18	43.52	39.87
60	36.33	40.03	43.42	43.83	40.90
Mean	32.93	35.18	38.75	39.18	
		SEm±		CD (P=0.05)	
Boron levels		0.53		1.52	
Potassium levels		0.53		1.52	
Interaction (B x K)		1.05		3.04	
Phosphorus uptake (kg/ha)					
0	8.37	8.15	8.21	8.65	8.35
15	9.46	10.40	11.84	12.26	10.99
30	10.43	11.50	13.34	13.73	12.25
60	11.40	12.38	13.63	13.65	12.76
Mean	9.92	10.61	11.76	12.07	
		SEm±		CD (P=0.05)	
Boron levels		0.17		0.47	
Potassium levels		0.17		0.47	
Interaction (B x K)		0.34		0.94	
Potassium uptake (kg/ha)					
0	3.90	3.91	3.96	4.32	4.02
15	4.75	5.27	6.16	6.20	5.59
30	5.97	6.73	7.85	7.91	7.12
60	6.52	7.45	8.02	8.09	7.52
Mean	5.28	5.84	6.50	6.63	
		SEm±		CD (P=0.05)	
Boron levels		0.15		0.31	
Potassium levels		0.15		0.31	
Interaction (B x K)		0.3		0.62	
Boron uptake (g/ha)					
0	8.56	14.93	15.45	16.32	13.82
15	10.36	19.97	23.39	26.16	19.97
30	12.44	22.40	30.99	32.00	24.46
60	12.94	24.17	30.88	32.63	25.15
Mean	11.08	20.37	25.18	26.78	
		SEm±		CD (P=0.05)	
Boron levels		0.6		1.75	
Potassium levels		0.6		1.75	
Interaction (B x K)		1.21		3.5	

The B x K interaction was found significant with respect to drymatter. Sunflower shoot uptake of major nutrients like N and P were significantly influenced by the application of B and K at 60 and 90 DAS.

Nutrient uptake by sunflower seed increased with increasing levels of boron and potassium application. Seed nutrient uptake of N, P, K and B were 43.83, 11.85, 13.65 kg ha^{-1} and 33.24 kg ha^{-1}, respectively with $B_{1.5}$ K_{60}, which is at par with B_1K_{30} treatment.

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