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Residual Impact of Nitrogen and Boron Application on growth and growth indices of mustard (*Brassica juncea* L.)

Tarun Sharma[1], Naveen Kumar[1], Akashdeep Singh[2]*, Bharat Bhushan Rana[1], Garima Chauhan[1], Dikshesh Rai[1], Sachin Kumar[3] and Meenakshi[4]

[1]*Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, HP, India.*
[2]*Faculty of Agriculture, School of Agricultural Sciences, Nirwan University, Jaipur, RJ, India.*
[3]*SGT University Gurugram 122505, Haryana India.*
[4]*Subject Matter Specialist (Agronomy), CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, HP, India.*

Abstract: The experiment was carried out in Research Farm of Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during the *rabi* seasons of 2021-22 and 2022-23 to study the residual effect of boron application on growth and growth indices of mustard crop.

The experiment had 15 treatments which were replicated thrice. T_1: $N_{60}K_{40}$ B1, T_2: $N_{60}K_{40}B_2$, T_3: $N_{60}K_{60}B_1$, T_4: $N_{60}K_{60}B_2$, T_5: $N_{120}K_{40}B_1$, T_6: $N_{120}K_{40}B_2$, T_7: $N_{120}K_{60}B_1$, T_8: $N_{120}K_{60}B_2$, T_9: $N_{180}K_{40}B_1$, T_{10}: $N_{180}K_{40}B_2$, T_{11}: $N_{180}K_{60}B_1$, T_{12}: $N_{180}K_{60}B_2$, T_{13}: Recommended dose of NPK (120:60:40), T_{14}: Recommended dose of NPK + Farmyard manure @ 10 t ha^{-1} and T_{15}: Absolute control in a randomized complete block design. Significantly higher plant height was recorded under treatment where higher dose of nitrogen (180 kg ha^{-1}) along with higher application of potassium (60 kg ha^{-1}) and boron (2 kg ha^{-1}) was done during both years of experimentation. Similarly, the highest absolute growth rate, crop growth rate and relative growth rate was recorded under $N_{180}K_{60}B_2$ treatment during both years of study. Boron application in the preceding season can influence the succeeding crop and therefore application of lower dose of boron in addition to residual boron cand recommended dose of fertilizer can substantially improve the growth of mustard crop.

Keywords*:* absolute growth rate, crop growth rate, mustard, residual boron.

1. INTRODUCTION

India is the fourth largest oil economy in the world, next to United States of America, China and Brazil. Oilseed crops account for 14.3% of the gross cropped area in India with total domestic production estimated to be 39.59 million tonnes (PIB, 2024). They are the second largest agricultural commodity after cereals, categorized in to two based on their sources *viz.*, primary source (groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower, castor, linseed and niger) and secondary source (rice bran, coconut, sal seed, mahua, maize seed, jojoba, neem, karanj, tobacco, etc.). Among oilseeds, mustard (*Brassica juncea* L.) is one of the most notable oilseed crops belonging to family Brassicaceae and commonly referred as *sarson* or *rai*. In India, mustard production during 2023-24 is estimated to be around 13.16 million tonnes majority being produced in the states of Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana and West Bengal. The seeds of mustard can be used as a whole (spice), crushed or for oil production. The oil has several uses such as cooking, lubricant, condiment in pickles, soap making, hair oil, etc. (Kumar, 2006). The by-product of oil extraction is the oil cake which can be used as manure, as supplemental feed for livestock, or may find their way to biorefinery for production of bioenergy, biopolymers, etc. (Mredul et al., 2022; Sarkar et al., 2021). Mustard seeds are rich source of unsaturated fatty acids, monounsaturated fatty acids (22.5%), polyunsaturated fatty acids

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(10.1%) (USDA, 2024). Besides, they contain 28.1% carbohydrates, 12.2% total dietary fiber and 26.1% protein (USDA, 2024). The oil content of mustard seed varies from 33-46% with recovery ranging between 32-38% (NCDEX, 2024).

Boron is one of the micronutrients essential for plant growth and development. It plays a significant role in synthesis of cell wall, root-shoot elongation, tissue differentiation and lignification (Patle and Singh, 2024). Yadav et al. (2016) reported significant increase in the yield attributes such as number of siliquae, length of siliquae and number of seeds per siliquae. Furthermore, a 52% increase in oil content was also reported with the application of 1.5 kg B ha^{-1}. The plant height and number of primary branches were significantly influenced with the application of 2.5 kg B ha^{-1} (Rahangdale et al., 2022). Similar findings were reported by Asirinaidu et al. (2022). Considering the importance of oil seed crops, current study was formulated to study the residual effect of boron application on the growth and growth indices of the subsequent mustard crop.

2. MATERIAL AND METHODS

The field experiment was conducted during the winter (*rabi*) season of 2021-22 and 2022-23 under the mid-hill conditions of Himachal Pradesh at the Research Farm of Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The research farm is located at an elevation of 1290 meter above mean sea level at latitude 32°6′ N and longitude 76° 3′ E. The experimental site falls under mid-hills sub-humid zone of Himachal Pradesh and is characterized by mild summers, cold winters and heavy rainfall during monsoon season. A composite soil sample was collected before the start of experiment from a depth of 0-15 cm. The sample was dried, grounded and sieved through 2mm sieve. The soil sample was processed for different soil physio-chemical properties. The soil was identified to be silty clay loam in texture with acidic reaction (pH 5.48). The soil was low in available nitrogen, medium in available phosphorus and available potassium.

The experiment was laid out in randomized complete block design comprising of 15 treatments which were replicated thrice. The details of the treatment are mentioned in Table 1. The treatments mentioned in the table were subjected to sweet sorghum crop in the previous cropping season and their residual effect in addition to the recommended dose of fertilizer application (N:P:K:S::60:40:40:20) was evaluated for the mustard crop during the period of investigation. The data was subjected to statistical analysis using R version 4.4.1. The least significant difference (LSD) was the post-hoc test employed to separate the treatment means using the package "agricolae". The visualizations were prepared using packages "ggplot2", "ggpubr", "dplyr" and "gridextra".

Table 1: Details of Treatments

Treatment No.	*Treatment*
T_1	$N_{60}K_{40}B_1$
T_2	$N_{60}K_{40}B_2$
T_3	$N_{60}K_{60}B_1$
T_4	$N_{60}K_{60}B_2$
T_5	$N_{120}K_{40}B_1$
T_6	$N_{120}K_{40}B_2$
T_7	$N_{120}K_{60}B_1$
T_8	$N_{120}K_{60}B_2$
T_9	$N_{180}K_{40}B_1$
T_{10}	$N_{180}K_{40}B_2$
T_{11}	$N_{180}K_{60}B_1$
T_{12}	$N_{180}K_{60}B_2$
T_{13}	Recommended dose of NPK (120: 60: 40)
T_{14}	Recommended dose of NPK + FYM @10 t/ha
T_{15}	Absolute control

3. RESULTS AND DISCUSSION

3.1. Plant Height

The analysis of plant height in mustard across different treatments and growth stages reveals significant variations (Fig 1). During the initial year, treatment where higher dose of nitrogen @ 180 kg ha^{-1} was applied in association with higher dose of potassium (60 kg ha^{-1}) and boron (2 kg ha^{-1}) during the previous cropping season resulted in significantly taller plants though this was at par with treatment where recommended dose of fertilizer along with application of farmyard manure @ 10 t ha^{-1}. The treatments where lowest dose of nitrogen either with higher or lower dose of potassium and boron was applied to soil during

the previous season resulted in significantly lowest plant height. Similar trend was observed up to 90 DAS. At 120 and harvest, during the second year of experimentation significantly tallest plants were observed under the treatment where recommended dose of fertilizer along with farmyard manure @ 10 t ha^{-1} was applied though this was at parity with treatments where higher dose of nitrogen (180 kg ha^{-1}) in combination with potassium and boron were applied. Nitrogen influences plant height in crops by stimulating various important physiological and biochemical processes. Nitrogen, a fundamental component of chlorophyll, improves photosynthetic efficiency, resulting in enhanced generation of carbohydrates required for vegetative development (Mu and Chen, 2021). This increase in photosynthesis leads to increased plant height because the plant can produce more energy and biomass. Furthermore, nitrogen is essential for the production of amino acids, which serve as protein building blocks. Proteins are essential for cell division, elongation, and overall plant growth (Kolukisaoglu 2020). Adequate nitrogen supply promotes protein synthesis, allowing for the formation of longer and stronger stems (Tegeder and Masclaux-Daubresse, 2018). Boron's residual effect also has a major impact on plant height in mustard crops, mostly via maintaining the structural integrity and functionality of cell walls, which influences cell division and elongation (Turan et al., 2018; Singh et al., 2010).

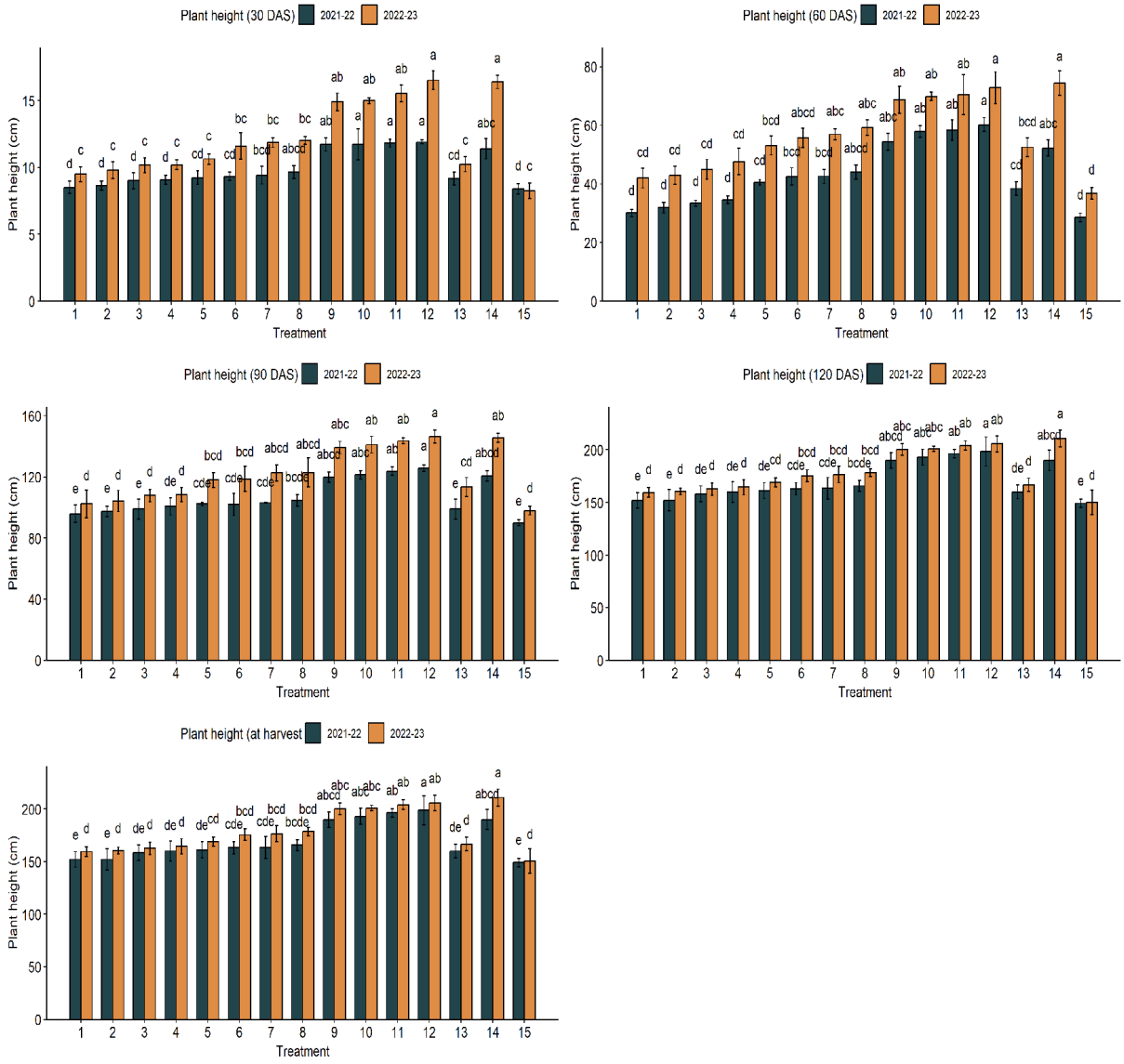

Figure 1: Effect of residual boron and recommended dose of fertilizers on plant height (cm) of mustard

3.2. Growth indices

Significant variations among absolute growth rate, crop growth rate and relative growth rate were recorded under the influence of residual boron and fertilizer application followed by the recommended dose of fertilizer to the mustard. Significantly higher absolute crop growth rate was recorded under treatment where higher dose of nitrogen in combination with higher dose of potassium and boron was applied during the previous cropping season during both years of study. Though the treatment was found to at parity with all other treatments containing higher dose of nitrogen and with recommended dose of fertilizer application either with or without the application of farmyard manure. Significantly lower absolute growth rate was recorded under treatment where lower dose of nitrogen application was supplied to the *kharif* season crop during *rabi* seasons of 2021-22 and 2022-23. Post 30-60 DAS, the absolute growth rate was not significantly affected by the treatments (Table 2).

The crop growth rate during 0-30 and 30-60 DAS was significantly highest under treatment subjected to higher application of nitrogen (180 kg ha^{-1}), potassium (60 kg ha^{-1}) and boron (2 kg ha^{-1}) during the preceding *kharif* season (Table 3). Though this treatment was found to be at parity with $N_{180}K_{60}B_1$ and $N_{180}K_{40}B_2$ treatments during both years of study. Significantly lower crop growth rate was recorded under treatment that was subjected to lower dose of nitrogen application in combination with potassium and boron, their concentration being irrelevant. Post 30-60 DAS, crop growth rate was not significantly influenced by the treatments. The relative crop growth rate also followed an almost similar trend to crop growth rate and remained non-significant during 30-60 DAS and at the time of harvest (Table 4).

Residual and applied nitrogen promotes vegetative growth and biomass production by playing an important role in photosynthesis, protein synthesis, and general metabolism. Adequate nitrogen guarantees a consistent supply of this crucial nutrient, encouraging continuous and strong plant growth and increasing dry matter accumulation (Mu and Chen, 2021). Similarly, boron is essential for cell wall production, membrane integrity, and reproductive development (Turan et al. 2018; Singh et al. 2010). Residual boron enhances food absorption and utilization, increases glucose transport, and promotes cell division and elongation (Bariya et al. 2014). These activities jointly improve the plant's structural integrity and growth efficiency, resulting in increased biomass accumulation reflected in the crop growth rate and relative growth rate.

Table 2: Effect of residual boron and recommended dose of fertilizers on absolute growth rate (cm day^{-1}) of mustard

Treatment	*0-30 DAS*		*30-60 DAS*		*60-90 DAS*		*90-120 DAS*		*120-harvest*	
	2021-22	*2022-23*	*2021-22*	*2022-23*	*2021-22*	*2022-23*	*2021-22*	*2022-23*	*2021-22*	***2022-23***
T_1	0.284	0.317	0.720	1.083	2.193	2.011	1.869	1.903	0.211	0.274
T_2	0.286	0.322	0.747	1.094	2.189	2.026	1.847	1.892	0.207	0.205
T_3	0.294	0.333	0.794	1.133	2.186	2.069	1.901	1.854	0.256	0.192
T_4	0.301	0.339	0.832	1.204	2.196	2.062	1.976	1.848	0.290	0.263
T_5	0.305	0.347	0.948	1.331	2.131	2.096	1.969	1.783	0.267	0.206
T_6	0.309	0.371	1.076	1.441	2.019	2.133	1.999	1.797	0.258	0.227
T_7	0.313	0.391	1.106	1.484	2.000	2.144	2.021	1.846	0.274	0.415
T_8	0.318	0.398	1.125	1.537	2.019	2.157	2.023	1.822	0.257	0.391
T_9	0.356	0.448	1.284	1.682	2.100	2.238	2.188	1.943	0.240	0.270
T_{10}	0.391	0.498	1.480	1.810	2.147	2.363	2.364	2.017	0.250	0.313
T_{11}	0.393	0.509	1.544	1.829	2.146	2.406	2.409	2.006	0.275	0.406
T_{12}	0.395	0.534	1.580	1.853	2.182	2.445	2.427	1.996	0.328	0.469
T_{13}	0.351	0.446	1.292	1.642	2.103	2.241	2.231	1.877	0.240	0.437
T_{14}	0.343	0.444	1.167	1.670	2.150	2.198	2.172	1.979	0.286	0.349
T_{15}	0.330	0.411	1.017	1.442	2.163	2.201	2.141	1.965	0.303	0.467
SEm±	0.025	0.024	0.095	0.125	0.238	0.263	0.347	0.394	0.114	0.143
LSD	0.052	0.049	0.194	0.256	NS	NS	NS	NS	NS	NS

Table 3: Effect of residual boron and recommended dose of fertilizers on crop growth rate (g m^{-2} day^{-1}) of mustard

Treatment	*0-30 DAS*		*30-60 DAS*		*60-90 DAS*		*90-120 DAS*		*120-harvest*	
	2021-22	*2022-23*	*2021-22*	*2022-23*	*2021-22*	*2022-23*	*2021-22*	*2022-23*	*2021-22*	*2022-23*
T_1	0.682	0.751	2.298	2.499	3.472	3.662	4.750	5.045	0.607	0.267
T_2	0.691	0.769	2.458	2.822	3.684	3.811	4.391	4.746	0.670	0.432
T_3	0.718	0.805	2.721	3.423	3.897	3.991	4.234	4.283	0.557	0.626
T_4	0.745	0.859	2.943	3.753	3.932	4.046	4.450	4.395	0.461	0.529
T_5	0.806	0.984	3.439	4.139	3.834	4.293	4.359	4.166	0.653	0.380
T_6	0.867	1.145	3.852	4.499	3.828	4.611	4.150	3.748	0.524	0.256
T_7	0.883	1.217	3.962	4.613	4.040	4.715	3.929	3.765	0.421	0.235
T_8	0.897	1.217	4.175	4.784	4.215	4.817	3.665	3.621	0.506	0.299
T_9	1.183	1.500	4.570	5.406	4.472	4.422	3.567	3.962	0.545	0.261
T_{10}	1.467	1.800	5.022	5.961	4.566	3.931	3.594	4.454	0.591	0.238
T_{11}	1.494	1.819	5.438	6.181	4.231	3.805	3.660	4.603	0.573	0.337
T_{12}	1.551	1.827	5.653	6.556	4.070	3.571	3.651	4.656	0.641	0.470
T_{13}	1.206	1.560	4.594	5.352	4.054	3.647	3.521	4.553	0.655	0.380
T_{14}	1.142	1.557	4.690	4.935	4.225	3.989	3.303	4.526	0.681	0.401
T_{15}	1.040	1.227	3.925	4.027	3.656	3.637	4.011	5.025	0.714	0.344
SEm±	0.052	0.066	0.324	0.301	0.477	0.613	0.690	0.709	0.328	0.239
LSD	0.107	0.135	0.664	0.617	NS	NS	NS	NS	NS	NS

Table 4: Table 2. Effect of residual boron and recommended dose of fertilizers on relative growth rate (g g^{-1} m^{-2} day^{-1}) of mustard

Treatment	*0-30 DAS*		*30-60 DAS*		*60-90 DAS*		*90-120 DAS*		*120-harvest*	
	2021-22	*2022-23*	*2021-22*	*2022-23*	*2021-22*	*2022-23*	*2021-22*	*2022-23*	*2021-22*	*2022-23*
T_1	0.1006	0.1038	0.0488	0.0487	0.0260	0.0253	0.0184	0.0183	0.0018	0.0007
T_2	0.1010	0.1045	0.0503	0.0512	0.0260	0.0243	0.0166	0.0166	0.0019	0.0011
T_3	0.1023	0.1060	0.0522	0.0553	0.0253	0.0222	0.0151	0.0140	0.0014	0.0016
T_4	0.1035	0.1082	0.0533	0.0561	0.0243	0.0210	0.0152	0.0137	0.0011	0.0013
T_5	0.1061	0.1126	0.0552	0.0551	0.0216	0.0203	0.0144	0.0123	0.0017	0.0009
T_6	0.1086	0.1177	0.0564	0.0533	0.0198	0.0199	0.0132	0.0104	0.0014	0.0006
T_7	0.1092	0.1199	0.0567	0.0522	0.0203	0.0198	0.0122	0.0102	0.0009	0.0005
T_8	0.1097	0.1198	0.0577	0.0533	0.0202	0.0196	0.0111	0.0097	0.0011	0.0007
T_9	0.1179	0.1262	0.0536	0.0513	0.0192	0.0167	0.0100	0.0100	0.0013	0.0006
T_{10}	0.1261	0.1330	0.0496	0.0486	0.0178	0.0137	0.0094	0.0108	0.0013	0.0005
T_{11}	0.1267	0.1333	0.0511	0.0493	0.0159	0.0130	0.0095	0.0110	0.0012	0.0007
T_{12}	0.1280	0.1335	0.0511	0.0507	0.0150	0.0119	0.0093	0.0109	0.0014	0.0009
T_{13}	0.1178	0.1277	0.0531	0.0491	0.0183	0.0149	0.0103	0.0121	0.0016	0.0008
T_{14}	0.1164	0.1276	0.0546	0.0474	0.0187	0.0164	0.0097	0.0121	0.0017	0.0008
T_{15}	0.1117	0.1155	0.0508	0.0489	0.0202	0.0198	0.0146	0.0164	0.0019	0.0007
SEm±	0.0017	0.0022	0.0030	0.0029	0.0029	0.0027	0.0021	0.0021	0.0009	0.0005
LSD	0.0034	0.0045	NS	NS	0.0059	0.0055	0.0044	0.0042	NS	NS

4. CONCLUSION

Present investigation-based outcomes revealed that higher application of nitrogen (180 kg ha^{-1}) in association with higher dose of potassium (60 kg ha^{-1}) and boron (2 kg ha^{-1}) followed by recommended dose of fertilizer application in mustard resulted in significantly higher plant height, absolute crop growth rate, and relative growth rate. Therefore, this investigation concluded that boron application in the preceding season can influence the succeeding crop and therefore application of lower dose of boron in addition to residual boron can substantially improve the growth of mustard crop.

Competing interests

Authors have declared that no competing interests exist.

Authors' Contributions

Author TS, NK, PK and GDS designed the study. Author TS, BBR, AS performed the statistical analysis. Author TS and AS wrote the first draft of the manuscript. Author GC and RS revised the manuscript. All authors read and approved the final manuscript."

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