Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(1): 1131-1134
Received: 25-11-2020
Accepted: 27-12-2020

Hardeep Singh
College of Agriculture, Guru Kashi University, Talwandi Sabo Punjab, India

Balwinder Singh Dhillon
College of Agriculture, Guru Kashi University, Talwandi Sabo Punjab, India

Nisha
College of Agriculture, Guru Kashi University, Talwandi Sabo Punjab, India

Corresponding Author:
Balwinder Singh Dhillon
College of Agriculture, Guru Kashi University, Talwandi Sabo Punjab, India

Effect of fly ash and phosphorus levels on the growth and yield of toria (*Brassica campestris* L. var. Toria)

Hardeep Singh, Balwinder Singh Dhillon and Nisha

Abstract
A field experiment entitled "Effect of fly ash and phosphorus levels on the growth and yield of toria (*Brassica campestris* L. var. Toria)" was conducted during *rabi* 2018-19 at Research Farm, Guru Kashi University, Talwandi Sabo, Bathinda (Punjab). The experiment was laid out in split plot design comprising three fly ash levels *viz.*, control (0 t/ha), 5 and 10 t/ha in main plots and four levels of phosphorous *viz.*, 0, 10, 20 and 30 kg P_2O_5/ha in sub plots. The results showed that the highest plant growth *viz.*, plant height and leaf area index, number of primary branches/plant and number of secondary branches/plant and yield attributing characters *viz.*, number of siliquae/plant, siliquae length, and 1000-seed weight and stover yield was recorded in fly ash @ 10 t/ha which was significantly higher over the control and fly ash @ 5 t/ha. Fly ash @ 10t/ha resulted in 5.42 and 11.79% higher seed yield than control and fly ash @ 5 t/ha, respectively. Phosphorous (P_2O_5) @ 20 kg ha^{-1} and 30 kg ha^{-1} recorded 35.3 and 40.4%, respectively higher seed yield than 0 kg P_2O_5 ha^{-1}. Application of P_2O_5 @ 20 and 30 kg ha^{-1} along with fly ash @ 10 t ha^{-1} produced statistically similar seed yield.

Keywords: Fly ash, phosphorous, seed yield, siliquae, stover yield and toria

Introduction
Toria (*Brassica campestris* L. var. Toria) belongs to cruciferae family is major oilseed crop in India. It occupies a prominent place toria being next to groundnut in both area and production in meeting the fat requirement in India. The origin of toria is eastern Afghanistan and adjoining parts of India and Pakistan. Toria is also known as sarson, rai or raya, lahi. Toria is tropical as well as temperate crop and required cool and dry weather for their proper growth. In India, it is grown in rabi season from September-October to February–March. Phosphorus (rates and mode of application) determine plant reproductive efficiency and play a vital role in growth and development of groundnut crop. The higher availability of phosphorus improved the physical environment with this treatment have contributed to higher yields of rice and wheat in successive years of reclaimination. Phosphorus (P) is the second major essential nutrient element for crop growth and good quality yield. The most obvious effect of P is on the plant root system. The requirement of P in nodulating legumes is higher compared to non-nodulating crops as it plays a significant role in nodule formation and fixation of atmospheric nitrogen (Brady and Weil, 2002) [2]. Due to the important role played by P in the physiological processes of plants, application of P to soil deficient in this nutrient leads to increase groundnut yield.

Fly ash is a coal combustion residue generated from thermal power plants during burning of coal. It is the finely dispersed solid waste consisting of partially or completely burnt or un-burnt particles of carbon. The mineralogical, physical and chemical properties of fly ash depend on the combustion, type of emission control devices, storage, and handling methods. Formation of fly ash depends on the ash content of coal. Indian coal used in power plants generally of low quality and has very high ash content (35-45%) as reported by Mathur *et al.* (2003) [9]. Instead of dumping as a waste material, the utilization of fly ash can be both economically viable and environment friendly (Mohan *et al.* 2012) [10]. Great emphasis is given to the ways and means of utilizing fly ash in various fields. Physico-chemical and biological properties of soil were found to vary due to fly ash amendment according to the original properties of soil and fly ash (Yeledhalli *et al.* 2012) [16]. Fly ash, when incorporated in crop fields by its transport from fly ash mounds/chimneys due to wind and rainfall actions or when used as soil amendment can modify the soil and crop canopy environment by enhancing the yield of crops (Sikka and Kansal 1995) [12].

Material and Methods

The research on the topic entitled "Effect of fly ash and phosphorus levels on the growth and yield of toria (*Brassica campestris* L. var. Toria)" was conducted at the Students Research Farm, Guru Kashi University, Talwandi Sabo (Bathinda) during *rabi* season of 2018-19. The farm is located at 29.9875ºN latitude and 75.0903ºE longitude with an altitude of 252 meters above the mean sea level as per are extreme. It is characterized by sub-tropical and semi-arid type of climate with hot and dry summer from April to June, hot and humid climate from July to September and cold winter from December to January. The maximum and minimum temperatures show considerable variations during both summer and winter seasons. Temperature often exceeds 38ºC during summer and sometimes touches 45ºC with dry spells during May and June. Minimum temperature falls below 0.5ºC with some frosty spells during the winter months of December and January. The average annual rainfall of the Talwandi Sabo (Bathinda) is 650 mm, about three-fourth of which is contributed by the south-west monsoon during July to September. Winter rains received in the months of December, January and February is scanty.

The mean temperature recorded during second week of 46th SMW2018 to first week of 9th SMW 2019 ranged between 9.8ºC in the 50th SMW to 26.9ºC in 9th SMW. The minimum weekly temperature ranged between 3.0ºC during crop growth period in the 49th SMW to 18.6ºC in 9^{h} SMW, whereas the maximum weekly temperature ranged between 14.3ºC in 50th to 35.1ºC in 9th SMW. The mean relative humidity varied from 54 to 88 per cent during crop growth period. The relative humidity during the same period varied from 76 to 99% in the morning and from 31 to 83% in the evening, the maximum being in the 50th, 52nd and 2nd SMWs (99%) and minimum in 12th and 14th SMWs (31%). Rainfall of 63.2 mm was recorded in six rainy days during crop season with maximum rainfall of 38.0 mm received during 3rd SMW in comparison to normal rainfall of 101.6 mm at Talwandi Sabo (Bathinda) during the same crop period. Evaporation during the crop season was 339.5 mm against normal evaporation of 360.2 mm.

The collected data were statistically analyzed by using Fisher's ANOVA technique and Critical difference (CD) test at 5% probability level was used to compare differences among treatment.

Results and Discussion

Growth parameters of toria

The plant height was found highest in fly ash @ 10 t/ha (137.8 cm) which was significantly higher than control (128.4 cm) and fly ash @ 5 t/ha (132.9 cm). Plant height (139.9 cm) was highest in 30 kg P_2O_5 ha^{-1}, which was significantly higher than control and 10 kg P_2O_5 ha^{-1} and it was statistically at par with 20 kg P_2O_5 ha^{-1}. These results corroborate with the findings of Dash *et al.* (2017) [3], Singh *et al.* (2006) [5] and Tomar *et al.* (2013) [15]. Interaction effect between fly ash and phosphorous levels with respect to plant height of toria was found to be non-significant. Leaf area index was highest in fly ash @ 10 ton/ha which was significantly higher than control and fly ash @ 5 t/ha. The highest leaf area index was found in 30 kg P_2O_5 ha^{-1}, being statistically at par with 20 kg P_2O_5 ha^{-1} and significantly higher than control (0 kg P_2O_5 ha^{-1}) and 10 kg P_2O_5 ha^{-1}. The interaction between fly ash and phosphorous levels of toria was non-significant. Similar results were also obtained by Akbari *et al.* (1988) and Lal *et al.* (1996) [8].

Maximum number of primary branches was observed in fly ash @ 10 t/ha (7.73) which was significantly higher than fly ash @ 0 (control) and 5 t/ha. Minimum number of primary branches (6.54) was observed in control crop. Khan *et al.* (1997) [7] also reported that 25% application of FA increased plant length, number of tillers and flowers of cosmos plant, whereas higher per cent reduced them significantly. The highest number of primary branches per plant (7.73) was recorded with 30 kg P_2O_5/ha, which was significantly higher than control, 10 and 20 kg P_2O_5/ha. The interaction effect between different fly ash and phosphorous levels showed that non-significant effect on number of primary branches per plant of toria.

Table 1: Effect of different levels of fly ash and phosphorus levels on growth parameters of toria

Treatments	Plant height (cm)	Leaf area index	No. of primary branches	No. of secondary branches
Fly ash levels (t/ha)				
0	128.4	1.42	6.54	10.3
5	132.9	1.45	7.15	10.8
10	137.8	1.54	7.73	11.0
LSD (P=0.05)	1.2	0.05	0.30	NS
Phosphorus levels (kg/ha)				
0	125.8	1.32	5.87	9.4
10	129.3	1.47	6.90	10.4
20	136.9	1.53	7.62	11.1
30	139.9	1.56	8.17	11.6
LSD (P=0.05)	4.5	0.04	0.38	0.5

There was significant difference among number of secondary branches per plant due phosphorous and no significant difference among number of secondary branches per plant due to fly ash levels. The highest number of secondary branches per plant was recorded under P_2O_5 applied at the rate of 30 kg ha^{-1}, which was significantly higher than control and 10 kg ha^{-1} and but it was statistically at par with 20 kg P_2O_5 ha^{-1}. Similar results have been reported by El- Habbasha *et al.* (2005) [4] and Gobarah *et al.* (2006) [5]. The interaction effect between different fly ash and phosphorous levels showed non-significant effect on number of secondary branches per plant of toria.

Yield attributing parameters of toria

Number of siliquae per plant positively increased with application of phosphorous and fly ash. Maximum number of siliquae per plant was observed in fly ash @ 10 t/ha (42.4), which was significantly higher than control (39.7) and fly ash @ 5 t/ha (40.7). The highest number of siliquae per plant (43.0) was recorded with 30 kg P_2O_5/ha, which was significantly higher than control, 10 and 20 kg P_2O_5/ha. The maximum number of siliquae per plant (44.4) was recorded in fly ash @ 10 t/ha with 40 kg P_2O_5/ha, but it was statistically at par with fly ash @10 t/ha with 20 kg P_2O_5/ha and significantly higher than all other treatment combinations of fly ash and nitrogen. The higher length of siliquae was observed in fly ash @ 10 t/ha (5.31 cm), which was significantly higher than control (5.16 cm) and it was statistically at par with fly ash @ 5 t/ha (5.30 cm). Length of siliquae significantly increases with the increasing levels of phosphorus. Application of 30 kg P_2O_5/ha gave the highest length of siliquae (5.48 cm), which were significantly higher than control and 10 kg P_2O_5/ha and it was statistically at par with 20 kg P_2O_5/ha. The interaction effect between fly ash and phosphorus levels was non-significant with respect to the length of siliquae.

Maximum number of seeds/siliquae (17.8) was observed in fly ash @ 10 t/ha which was significantly higher than control (15.6) and fly ash @ 5 t/ha (16.6). Minimum number of seeds/siliquae was observed in control treatment. The highest number of seeds/siliquae (19.2) was recorded in 30 kg P_2O_5 ha^{-1} treatment and it was significantly higher than 0 and 10 kg P_2O_5 ha^{-1} treatments, but it was statistically at par with 20 kg P_2O_5 ha^{-1}. The lowest number of seeds/siliquae (14.3) was found in the control treatment (0 kg P_2O_5 ha^{-1}). The interaction effect between different fly ash and phosphorous levels showed that non-significant effect on number of seeds/siliquae of toria. The highest 1000-seed weight was recorded in fly ash @ 10 t/ha. However, 1000-seed weight significantly increased with the increasing levels of phosphorous. Application of 30 kg P_2O_5 ha^{-1} gave the highest 1000-seed weight (4.43 g) which was statistically at par with 20 kg P_2O_5 ha^{-1} and significantly higher than control and 10 kg P_2O_5 ha^{-1}. Similar results were also reported Biswas *et al.* (2009) [1] and Khan *et al.* (2017) [6]. The interaction effect was found to be non significant between fly ash and phosphorous levels.

Table 2: Effect of different fly ash levels and phosphorus levels on productive parameters of toria crop

Treatments	No. of siliquae/plant	Length of siliquae	No. of seeds/siliquae	Test weight (g)
Fly ash levels (t/ha)				
0	39.7	5.16	15.6	4.27
5	40.7	5.30	16.6	4.35
10	42.4	5.31	17.8	4.43
LSD (P=0.05)	1.3	0.05	0.2	NS
Phosphorus levels (kg/ha)				
0	37.7	4.98	14.3	4.27
10	40.8	5.20	16.0	4.33
20	42.2	5.37	17.1	4.38
30	43.0	5.46	19.2	4.43
LSD (P=0.05)	0.7	0.11	1.2	0.05
F x P	1.0	NS	0.4	NS

Productivity of toria

The highest seed yield was observed in fly ash @ 10 t/ha (10.90 q/ha), which was significantly higher than control (9.75 q/ha) and fly ash @ 5 t/ha (10.34 q/ha). Fly ash @ 10t/ha resulted in 5.42 and 11.79% higher seed yield than control and fly ash @ 5 t/ha, respectively. The highest seed yield (11.74 q ha^{-1}) was obtained in 30 kg P_2O_5 ha^{-1} which was significantly higher than other phosphorous levels *viz.*, 0 kg P_2O_5 ha^{-1} (8.36 q/ha) and 10 kg P_2O_5 ha^{-1} (9.90 q/ha), but it was statistically at par with 20 kg P_2O_5 ha^{-1} (11.31 q/ha). The lowest grain yield obtained was in control (0 kg P_2O_5 ha^{-1}). Phosphorous (P_2O_5) @ 20 kg ha^{-1} and 30 kg ha^{-1} recorded 35.3 and 40.4%, respectively higher seed yield than 0 kg P_2O_5 ha^{-1}. Similar results were also reported by Saini *et al.* (2010) [11] and Singh and Singh (1986). The interaction effect between fly ash and phosphorous levels on grain yield was found to be significant. The highest grain yield (12.47 q ha^{-1}) was recorded in plots treated with the application of P_2O_5 @ 30 kg ha^{-1} along with the application of fly ash @ 10 t ha^{-1} and it was statistically at par with 20 kg P_2O_5 ha^{-1} and application of fly ash @ 10 t ha^{-1}. The lowest grain yield (7.33 q ha^{-1}) was recorded in plots treated with P_2O_5 @ 0 kg ha^{-1} along with phosphorous @ 0 kg P_2O_5 ha^{-1}.

Stover yield of toria was not significantly influenced by fly ash application. The highest stover yield was recorded in control and fly ash @ 5 t/ha. Stover yield of toria varied significantly due to phosphorous levels. The highest stover yield (24.3 q ha^{-1}) was obtained in 30 kg P_2O_5 ha^{-1} which was significantly higher than other phosphorous levels *viz.*, 0 kg P_2O_5 ha^{-1} (18.4 q ha^{-1}) and 10 kg P_2O_5 ha^{-1}(21.3 q ha^{-1}), but it was statistically at par with 20 kg P_2O_5 ha^{-1} (23.9 q ha^{-1}). The lowest stover yield obtained was in control (0 kg P_2O_5 ha^{-1}). The interaction effect between fly ash and phosphorous levels on stover yield was found to be non-significant.

Table 3: Effect of different levels of fly ash and phosphorus on the productivity of toria

Treatments	Seed yield (q/ha)	Stover yield (q/ha)	Biomass yield (q/ha)	Harvest index (%)
Fly ash level (t/ha)				
0	9.74	22.0	31.7	30.6
5	10.34	22.0	32.3	31.9
10	10.90	21.9	32.8	33.2
LSD (P=0.05)	0.32	NS	0.3	NS
Nitrogen levels (Kg/ha)				
0	8.36	18.4	26.8	31.1
10	9.90	21.3	31.2	31.7
20	11.31	23.9	35.2	32.2
30	11.74	24.3	36.0	32.6
LSD (P=0.05)	0.58	0.5	0.9	NS
F x P	0.70	NS	NS	NS

Biomass yield of toria was significantly influenced by fly ash application. The highest biomass yield was recorded in fly ash @ 10 t/ha which was significantly higher than control and fly ash @ 5 t/ha. Biomass yield increased significantly with the increase in phosphorous levels. The highest biological yield (36.0 q ha^{-1}) was recorded in 30 kg P_2O_5 ha^{-1} which was significantly higher than other phosphorous levels *viz.*, 0 kg P_2O_5 ha^{-1} (26.8 q ha^{-1}) and 10 kg P_2O_5 ha^{-1}(31.2 q ha^{-1}), but it was statistically at par with 20 kg P_2O_5 ha^{-1} (35.2 q ha^{-1}). The lowest biological yield was recorded in control (0 kg P_2O_5 ha^{-1}). The interaction effect between fly ash and phosphorous levels on biological yield was found to be non-significant. Harvest index is an important parameter indicating the efficiency of partitioning of dry matter to the economic parts of the crop. Higher value of harvest index indicates that plant is more efficient in producing economic yield. The data indicated that application of fly ash and phosphorous levels had no effect on harvest index.

Conclusions

On the basis of results summarized it can be concluded that fly ash @ 10 t/ha was found to be most effective in toria for achieving higher yield in toria crop. Fly ash @ 10 t/ha resulted in 5.42 and 11.79% higher seed yield than control and fly ash @ 5 t/ha, respectively. Phosphorous (P_2O_5) @ 20 kg ha^{-1} and 30 kg ha^{-1} recorded 35.3 and 40.4%, respectively higher seed yield than 0 kg P_2O_5 ha^{-1}. Application of P_2O_5 @ 20 and 30 kg ha^{-1} along with fly ash @ 10 t ha^{-1} produced statistically similar seed yield.

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