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Effect of foliar nutrition on growth, oil yield, production economics of hybrid mustard (*Brassica juncea* L.) and soil microbial properties

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Abstract
An experiment was undertaken during two consecutive *rabi* seasons of 2018-19 and 2019-20 on Kesari-5111, a hybrid mustard variety by foliar application to adjudge the growth parameters, seed and oil yield, soil microbial properties and production economics under alluvial soil West Bengal, Nadia. Treatment combinations imposed were nine revealed that plot treated with of di-ammonium phosphate (DAP) at 2% has recorded best in terms of vegetative as well as yield, quality attributes and production economics. The bacterial population were improved at ($ZnSO_4.7H_2O$) at 2g litre^{-1}of water and for fungi and actinomycetes population significantly greater value was obtained with foliar application of DAP@2% (20 g litre^{-1}) at flowering stage and harvest respectively.

Keywords: Growth, oil yield, production economics, soil microbial status and hybrid mustard

Introduction
Rapeseed-mustard is one of the major oilseed crop in India and around the world ranks fourth in production after Canada, China and the European Union with an area, production and productivity of 36.81 million ha, 72.99 million tonnes and 1983 kg/ha, respectively in the world. Rapeseed-mustard was cultivated on 6.83 million ha in India, reporting a domestic production of 9.12 million tonnes and a productivity of about 1.33 t/ha (Anonymous, 2021) [2]. In general mustard seed contains 30-33% of oil, 18-27% proteins, 9-11% fibres and 10-12% extractable substances (Sudhir *et al*., 2013) [14]. Foliar application is a method of applying fertilizer in liquid form with smaller quantities of nutrients directly on above ground plant parts without causing any detrimental effect. Foliar application is an important alternative of fertilization in modern agriculture due to its ability to mitigate the stresses, eliminating loss through leaching by reducing the problems like fixation and immobilization of nutrients and improves in efficient utilization of a nutrient required for proper growth and yield. Furthermore, In agriculture foliar application has several advantages over soil application for its environmental friendly nature, immediate and target-oriented action, better translocation of nutrients that can be directly applied during the critical growth stages. Nitrogen is key elements of the chlorophyll that promotes plant to capture solar energy through photosynthesis which enhances growth and yield of crop plants. Phosphorus have a vital role in photosynthesis, respiration, cell enlargement that promotes crop growth, root development and high seed yield (Hachiya and Sakakibara, 2016) [15]. Though potassium is not a constituent of any organic compound but played a crucial in promoting growth playing a vital role in plant metabolism as a co-factor for many enzymes and controls movement of stomata, tolerance to diseases, drought (Singh *et al*., 2010) [13]. Micronutrients like Sulfur is a important source for activation of essential enzymes that enables the synthesis of cysteine, methionine, chlorophyll, vitamins (B, biotin and thiamine), carbohydrate metabolism that plays a role in increasing in yield of mustard oil content, protein content, fatty acid and glucosinolate in mustard**.** Boron helps in promoting of cell wall and membrane structural integration anther formation, pollen germination that boosts yield and quality of crop produce. Zinc involves in auxin synthesis that enables a vital role in enhancing enzymatic as well as physiological activities of the plant system. Salicylic acid is an important growth regulator plays an important role in plant accumulation of photosynthates, transpiration and involved in plant defense action against infection by various pathogen. Therefore, the experiment was laid out to investigate the role of foliar application (macro, micromutrients and growth regulator) on growth, seed and oil yield, soil microbial properties and production economics of hybrid mustard.

Materials and Methods

The experiment conducted during *rabi* seasons of 2018-19 and 2019-20 at the Instructional Farm (22°93'N latitude, 88°53' E longitude and 9.75 m above mean sea level) of Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal in medium land condition. The average rainfall was 1440 mm, 75% of which was received during the month of June to September period. The experimental soil was neutral in reaction (pH 6.68), having soil organic carbon 0.54%, available N 196.4kg ha^{-1}, P_2O_5 29.2kg ha^{-1} and K_2O 192.1 kg ha^{-1}. Meteorological data pertaining to the cropping seasons revealed that maximum temperature ranged between 23.34ºC to 33.99ºC with minimum temperature prevailed between 9.97ºC to 18.04ºC. The maximum and minimum relative humidity ranged between 94.06 to 97.21% and 44.93 to 59.56%, respectively. It was carried out at randomized complete block design (RCBD) along with three replications comprising of nine different foliar application treatments *viz*. T_1- No foliar spray (Control);T_2- Water spray; T_3- Urea (46% N) at 2% (20 $glitre^{-1}$ of water); T_4-DAP (NPK-18:46:0) at2% (20 $glitre^{-1}$ of water); T_5- Water soluablesulphurate0.5% (5 $glitre^{-1}$ of water); T_6-NPK (grade 19:19:19) at 1% (10 $glitre^{-1}$ of water); T_7- Zinc (in form of $ZnSO_4.7H_2O$) at 0.2% (2 $glitre^{-1}$ of water); T_8- Boron (in form of Borax) at0.1% (1 $glitre^{-1}$ of water); T_9- Salicylic acid 100 ppm. The seeds of hybrid mustard var. 'Kesari-5111' were sown at 30 cm (row to row) × 10 cm (plant to plant) spacing in the plots of size 5m × 4m. Nitrogen, phosphorus and potassium was applied @100, 50 and 50 kg ha^{-1} respectively across all treated plots. Half of total recommended N along with full recommended dose of P_2O_5 and K_2O were applied at the time of land preparation) and rest was applied at 30 days after sowing (DAS).The foliar application was given at critical stages including the pre-flowering and siliqua formation stage at 45 and 60 DAS, respectively. Thinning was done to maintain described plant spacing according to the combination. Weeding was done at 20 DAS and 40 DAS to reduce the resource competition between plant and weed. All the plots were separated by about 15 cm ridges. After harvesting, soil samples were collected from individual plots, dried and powdered. Two light irrigations at pre-sowing and subsequent stages were given. The data of plant height were collected from 30, 60, 90 DAS in all the treatments expressed in centimeters (cm). The leaf area was calculated at 30, 60, 90 DAS manually. In mustard crop 10 circular leaf pieces of each measured 23.74 cm^2each were punched out. The area of the leaf cut portion was determined afterwards. The whole of the cut pieces and leaflets were dried of the leaves separately and the weight of the samples was recorded. Dry matter accumulation was taken of different plant parts excluding the underground portion of the plan from an area of $1m^2$ and it is expressed in gm/m^2.Yield also calculated through standard procedure. To estimate the soil microbial population soil water extract of each treatments was cultured. For bacterial counts, the soil extract at a concentration of 10^{-5} and 10^{-6} was inoculated in Nutrient Glucose Agar medium and noted on 3rd day. The extract was inoculated at a concentration of 10^{-3} and 10^{-4} in Rose Bengal Agar medium and the counts were calculated on 4th day for assessing the fungal population. For counting actinomycetes population, the soil water extract was injected in Kenknight's Agar medium at a concentration of 10^{-4} and 10^{-5} and count was taken on 11th day. The population of microorganisms was expressed in ten thousand. The identification of fungi and actinomycetes were based on their morphology. All the data were statistically analysed by OPSTAT (online statistical analysis tool) and also pooled analysis of two years' data was done.

Result and Discussion

Plant height

Initially, at 30 DAS there was no significant difference on plant height of mustard crop between the treated and control. At 60 DAS highest plant height (105.3cm) recorded at DAP @ 2% which was statistically at par with treatment Urea@2% of plant height of 98.7cm. At 90 DAS and harvest, the highest plant height of 177.1 cm was recorded at treatment DAP@ 2% followed by treatment Urea@2% recording the plant height of 171.3cm. The lowest plant height of 66.1 cm and 108.7 cm was obtained at control (no foliar application) at 60 DAS and 90 DAS respectively. Thus, it was clear from the experimental results that height of hybrid mustard was remarkably effected by the foliar nutrition management practices. The highest plant height was recorded at DAP@ 2%was attributed to increase of phosphorus and nitrogen availability to plant absorbed sufficient quantity of phosphorus and nitrogen to maturity, which influenced the crop growth. Greater plant height receiving adequate nutrition results performs better in metabolic activities by the crop**.** Plant applied with balanced doses of sulphur accumulating best quantities of photosynthates which will be translocated to sink site in pods and seeds.

Leaf area index (LAI)

Leaf area index (LAI) of hybrid mustard variety was progressed with the increased in crop age up to 60 DAS, after that the LAI was declined**.** Initially at 30 DAS there was no significant difference between the treated and control. At 60 DAS highest value of leaf area index (4.27) recorded at Urea@ 2% which was statistically at par with treatment DAP@ 2%ofLAI value 4.15. The highest LAI was obtained at 60 DAS where foliar application of Urea (46% N) followed by DAP (NPK-18:46:0) applied, because of more nitrogen availability helps in better growth and development of leaves and so, Urea @ 2% finds best result on leaf area index (LAI). The leaf area index (LAI) of hybrid mustard was significantly different between foliar nutrition levels at all growth stages. These results are inconformity with the findings of Sharma *et al.*, 2008 [10] and they reported that generally, the higher doses of nitrogen fertilizer lead to a higher value in leaf area index in oilseeds, although LAI uniformly declined at all the fertilizer levels after attaining the peak LAI.

Dry matter accumulation

The dry matter accumulations (DMA) were recorded on 30 and 60 DAS Irrespective of different foliar applications, the total dry matter accumulation per plant were increasing with the age of the crop. Initially at 30 DAS, there is a little significant differences were noticed on this hybrid mustard variety. But at 60 DAS, the highest dry accumulation ($363.1g/m^2$) was found at treatment, applied with DAP @ 2%, which is statistically at par with Urea @ 2%, obtaining dry matter accumulation of 352.7 g/m^2.The lowest value of dry matter accumulation($283.1g/m^2$) was calculated at control (no foliar spray) at 60 DAS. The dry matter accumulation shows highest result at DAP (NPK-18:46:0)@2% as against to T_3 [Urea (46%N) @ 2%] due to availability of nitrogen and

phosphorus assists in better growth and development of crop. The result is agreement with findings of Singh and Rathi 2010 and they reported that the different levels of nitrogen significantly influenced LAI as well as dry matter accumulation.

Crop growth rate

The crop growth rate (CGR) of hybrid mustard crop grown in new alluvial soil of West Bengal was significantly influenced by the different treatments of foliar nutrition application. The highest value of crop growth rate (CGR) (11.6 g/m^2/day) at 30-60 DAS was recorded from DAP @2% which is followed by Urea @2% (11.2g/m^2/day). Different foliar nutrition application significantly influenced the LAI, total dry matter accumulation as well as CGR. Higher values in terms of crop growth rate were recorded from treatments of foliar application with best in LAI values may be due to higher light interception by leaves followed by higher photosynthesis and accumulation of more photosynthates.

No. of leaves/plant

The highest value of number of leaves per plant (9.37) and (26.33) was obtained from DAP at 2% which was followed by NPK (19:19:19)@1% at 30 DAS and 60 DAS interval respectively. For 90 DAS same trend was followed DAP at 2%*i.e*highest value of (96.73) and the lowest value in terms of number of leaves per plant was calculated from Control *i.e* (No foliar spray) at 30 DAS, 60 DAS and 90 DAS.

Table 1: Effect of foliar application on growth parameters of hybrid mustard (Pooled data of 2 years)

Treatment	Plant height (cm)			Leaf area index		Dry matter accumulation(g/m^2)		Crop growth rate(g/m^2/day)	No. of leaves/plant		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30-60 DAS	30 DAS	60 DAS	90 DAS
T_1	20.9	66.1	108.7	0.33	2.65	11.0	283.1	9.1	7.30	23.50	83.33
T_2	20.3	69.5	116.2	0.34	2.31	12.0	287.3	10.1	7.33	24.30	92.67
T_3	19.7	98.7	171.3	0.31	4.27	16.7	352.7	11.2	8.87	25.57	86.20
T_4	19.4	105.3	177.1	0.29	4.15	17.1	363.1	11.6	9.37	26.33	96.73
T_5	20.3	79.7	141.7	0.33	3.53	14.1	336.6	10.2	8.00	24.87	88.37
T_6	20.4	88.7	148.5	0.30	3.85	16.3	348.2	11.3	9.00	26.07	85.19
T_7	19.6	77.1	138.2	0.37	3.51	13.6	327.3	10.4	8.20	24.67	78.33
T_8	19.4	81.5	143.2	0.32	3.89	14.5	341.7	10.9	8.43	25.10	73.23
T_9	19.5	92.7	164.8	0.31	3.71	12.7	319.6	10.2	7.90	24.40	71.27
SE (d)	0.25	7.61	9.02	0.02	0.10	0.36	7.52	0.11	0.07	0.20	0.39
CD (P= 0.05)	NS	22.1	26.2	NS	0.30	1.06	22.0	0.31	0.15	0.42	0.80

T_1- Control(No foliar spray); T_2- Water Spray; T_3- Urea @ 2% (20 glitre^{-1}of water); T_4- DAP @ 2% (20 glitre^{-1}of water); T_5- Water soluable sulphur @0.5% (5 glitre^{-1}of water); T_6- NPK (19:19:19) @ 1% (10 glitre^{-1}of water); T_7- Zinc ($ZnSO_4.7H_2O$) @ 0.2% (2 glitre^{-1} of water); T_8- Boron (Borax) @ 0.1%(1glitre^{-1}ofwater);T_9-Salicylicacid100ppm(100mglitre^{-1}ofwater)

Seed yield (kg/ha)

Differential fertility gradient created in hybrid mustard by the application of different combination of nutrients(macro and micro) that results in significant variation in seed yield of hybrid mustard cv. *Kesari- 5111* ranging from 1087 to 1971 kg/ha and the yield increase was to tune of 15.80 to 81.32% (Table 2). In this experiment, the highest seed yield (1971kg/ha) was recorded in the treatment where application of DAP @ 2% followed by sulphur @ 0.5% obtaining the seed yield of 1867 kg/ha. A good seed yield 1705 kg/ha also was obtained with foliar application of Boron (Borax) @ 0.1%. Adequate supply of major nutrition at the time of reproductive stage attained higher crop yield (Sarkar *et al*., 2021) [7].

Oil yield (kg/ha)

In case of oil yield, best result has been found at DAP @ 2% which is followed by Boron @ 0.1%) (Table 2). The oil yield has found 699.8 kg/ha and 660.1kg/ha, respectively in DAP @ 2% and Boron@ 0.1%. The lowest oil yield (366.5 kg/ha) was recorded from control (no foliar spray) and it was significantly lower than other treatments of foliar nutrition. Oil content and oil yield was increased in hybrid mustard seed due to the foliar nutrition through which nutrients are supplied in adequate amount. Combined foliar nutrients spray recorded enhancing the oil content leading to higher oil yield as a result of enhanced seed yield (Sharma 2012) [9].

Soil microorganism population

The impact of application of different foliar nutrition on bacteria (*Pseudomonus fluorescence*), fungi (*Trichoderma viridae*, *Trichoderma harzianum*) and actinomycetes were recorded (Table 2). Results revealed that treatments with foliar nutrition caused significant changes in soil micro-flora. Application of Zinc ($ZnSO_4.7H_2O$) @ 0.2% (2 glitre^{-1} of water) resulted in significantly greater bacterial population 68 CFU x 10^5/g of soil and 75 CFU x 10^5/g of soil at flowering and after harvest respectively. The fungi population were improved with foliar application of soluble sulphur @ 0.5% (5 g litre^{-1} obtaining value of 49.6 CFU x 10^3/g of soil and 53.6 CFU x 10^3/g of soil at flowering and after harvest of crop respectively.

In case of actinomycetes population foliar spray of DAP @ 2% (20 glitre^{-1}of water) obtaining value of 55 CFU x 10^5/g of soil and 58 CFU x 10^5/g of soil at flowering and after harvest respectively. Results might be attributed to the fact that humic acid accelerates root exudation during later stages of the incubation period, which is responsible for microbial activity and nutrient availability in rhizosphere soil (Norton *et al*., 2009) [5].

Table 2: Effect of foliar application on seed yield, oil yield and microbial population of hybrid mustard (Pooled data of 2 years)

Treatment	Seed yield (kg/ha)	Oil yield (kg/ha)	Microbial population					
			Bacteria (CFU x 10^5/g of soil)		Fungi (CFU x10^3/g of soil)		Actinomycetes (CFU x 10^5/g of soil)	
			Flowering	After Harvesting	Flowering	After Harvesting	Flowering	After Harvesting
T_1	1087	366.5	30	54	31.2	37.2	28	37
T_2	1143	403.6	31	58	36.5	42.5	35	40
T_3	1740	630.1	51	66	40.2	45.2	45	51
T_4	1971	699.8	53	69	48.3	52.3	55	58
T_5	1867	647.2	60	72	49.6	53.6	50	54
T_6	1680	624.9	55	64	43.4	49.4	40	43
T_7	1568	604.0	68	75	46.1	50.1	35	42
T_8	1705	660.1	57	60	39.5	40.5	51	46
T_9	1243	625.0	51	55	44.8	49.8	56	42
SE (d)	56.65	9.38	-	-	-	-	-	-
CD (P= 0.05)	164.66	27.21	-	-	-	-	-	-

T_1- Control (No foliar spray); T_2- Water Spray; T_3- Urea @ 2% (20 glitre^{-1}of water); T_4- DAP @ 2% (20 glitre^{-1} of water); T_5- Water soluable sulphur @0.5% (5 glitre^{-1} of water); T_6- NPK (19:19:19) @ 1% (10 glitre^{-1} of water); T_7- Zinc ($ZnSO_4.7H_2O$) @ 0.2% (2 glitre^{-1} of water); T_8- Boron (Borax) @ 0.1% (1 glitre^{-1}ofwater); T_9- Salicylic acid 100ppm (100 mglitre^{-1} of water)

Economic analysis of hybrid mustard of cultivation

Among all the treatments, lower cost of cultivation (Rs.32750.00 ha^{-1}) was observed with no foliar spray, while highest cost of cultivation (Rs.39427.1 ha^{-1}) was noticed with T_5 [water soluable sulphur @ 0.5% (5g/litre of water) (Table 3). Highest gross returns (Rs.77125.4 ha^{-1}) were obtained with water soluble sulphur @ 0.5% (5g/litre of water) and lowest gross returns (Rs.61313.3 ha^{-1}) were obtained with no foliar spray. With regard to net returns DAP @ 2% (20 g per litre of water)] recorded higher net returns (Rs.39416.6 ha^{-1}), after this treatment [Urea @ 2% (20g per litre of water] recorded relatively higher net returns (Rs.38786.5 ha^{-1}) while lowest net returns (Rs.28563.3 ha^{-1}) were obtained with control (no foliar spray). The Benefit- cost ratio was higher (2.1) with DAP@2% (20g per litre of water) and lowest B:C ratio of 1.77 was noticed with water spray.

Table 3: Effect of foliar nutrition on production economics of hybrid mustard (pooled data 2 years)

Treatments	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs. /ha)	B:C ratio
T_1	32750.0	61313.3	28563.3	1.87
T_2	34827.2	61869.8	27042.6	1.77
T_3	36256.0	75042.5	38786.5	2.05
T_4	35604.2	75020.8	39416.6	2.10
T_5	39427.1	77125.4	37698.3	1.95
T_6	37104.2	75309.9	38205.7	2.02
T_7	38783.3	76519.7	37736.4	1.97
T_8	33427.1	63306.4	29879.3	1.89
T_9	37487.3	65326.7	27839.4	1.74

T_1-Control(No foliar spray); T_2- Water Spray; T_3- Urea @ 2% (20 glitre^{-1}of water); T_4- DAP @ 2% (20 glitre^{-1}of water); T_5- Water soluable sulphur @0.5% (5 glitre^{-1}of water); T_6- NPK (19:19:19) @ 1% (10 glitre^{-1}of water); T_7- Zinc ($ZnSO_4.7H_2O$) @ 0.2% (2 glitre^{-1} of water); T_8- Boron (Borax) @ 0.1% (1g litre^{-1} of water); T_9-Salicylicacid 100ppm (100mg litre^{-1} of water)

Conclusion

Conclusively, application of foliar nutrition was found to be superior for enhancing growth and yield and microbial status of hybrid mustard (var. Kesari- 5111). Among the foliar nutrition treatments, application of DAP at 2% in conjunction with RDF (N, P_2O_5 andK_2O at 100, 50 and 50 kg ha^{-1}) were found to be more beneficial in terms of growth, seed yield and B:C ratio. Hence, we suggest an integration of RDF (N, P_2O_5 and K_2O @ 100, 50 and 50 kg ha^{-1}) with foliar application of DAP @ 2% (20 g litre^{-1}of water) at pre-flowering and siliqua initiation stages (at 45 and 60 DAS), respectively not only to augment growth and seed yield of hybrid mustard but also to improve soil microbial population in Gangetic plains of West Bengal.

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