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Impact of Crop-specific Technologies and Organic Growth Stimulants on Mustard, Black Gram and Green Gram in Sundarban area of West Bengal

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The gap between actual and potential crop production can be minimized by maintaining plant health, which needs crop-specific technology interventions. On-farm trials were conducted during 2017-18 and 2018-19 in the farmers' fields in the Sundarbans to study the impact of crop-specific technologies on crop yields. The yield of mustard can be increased by about 47% with the installation of *Apis mellifera* bee hives @ 3 ha^{-1} while it was about 40% in the case of *A. cerena* type @ 5 ha^{-1}. A considerable increase (30.17% and 20.90%) in pod setting was recorded via the installation of mellifera bee hive and cerena type, respectively. Spraying of *panchagavya* @ 5%, *sasyagavya* @ 5%, and *dasaparni* @ 1% at 30 days after sowing (DAS) onwards at 15 days intervals, in alternate application with 600 L ha^{-1} of *jeevamrit* as soil application at 30 DAS boosted the plant growth attributing characters in black gram. The same treatment recorded the highest yield of blackgram (0.95 t ha^{-1}), lowest infestation of pod borer (8.6%) and lowest powdery mildew infestation (21.20%). Application of *beejamrit* for seed bio-priming and 5% jeevamrit at 30 and 45 DAS as spray and soil application @ 600 L ha^{-1} also showed potential results with 30% increased yield of black gram over existing farmers' practices. The integrated approach consisting of the application of *Trichoderma viride* enriched cow dung @ 750 kg ha^{-1}, seed treatment with carboxin 17.5% + thiram 17.5% @ 3 mL kg^{-1} seed, installation of pheromone trap @ 30 ha^{-1} and need-based spot application of *neemastra* @ 3% resulted in highest seed yield of greengram (0.94 t ha^{-1}) and B:C ratio (3.38) followed by chemical management (0.93 t ha^{-1}, 3.23).

(***Key words:*** *Black gram, Green gram, Honey bee, Mustard, Organic biostimulant)*

Mustard (*Brassica* sp.) and pulses (mainly black gram and green gram) are two important field crops cultivated across India and play an important role in the national economy. West Bengal has diverse agro-ecological conditions to grow all the oilseeds cultivated in India, of which rapeseed-mustard and sesame are the most predominant crops followed by groundnut, linseed, and sunflower; while among pulses, lentil is the most predominant crop followed by black gram (*Vigna mungo*), khesari (*Lathyrus sativus*), Bengal gram (*Cicer arietinum*), green gram (*Vigna radiata*) and field pea (*Pisum sativum*). South 24 Parganas district has wide variability in ecology, the geographical location stretching from the metropolitan Kolkata to the remote riverine villages upto the mouth of Bay of Bengal. Thus, the district shows an array of variability in agriculture cropping patterns. The district covers a major share of mustard, black gram (0.470 thousand tonnes) and green gram production (11.399 thousand tonnes) as per the report of the Bureau of Applied Economics and Statistics (2016). Whereas, the productivity of aforesaid crops is quite low as compared to the highest producing districts (mustard: 1.26 t ha^{-1} in comparison to 1.33 t ha^{-1}, black gram: 0.78 t ha^{-1}as against 0.92 t ha^{-1}; green gram: 0.59 t ha^{-1} compared to 1.67 t ha^{-1}) (Bureau of Applied Economics and Statistics, 2016). Besides, the low productivity of mustard is associated with several issues like low use of sulphur, boron and phosphatic fertilizer (Jaiswal *et al.,* 2015). Poor plant health management coupled with the infestation of aphids (*Lipaphis erysimi* Kalt.) is the most important determinant factor causing up to 97.6% yield losses in mustard (Shah *et al.,* 2015). Though South 24 Parganas district accounts for the highest production of green gram (11.40 thousand MT) among the districts of West Bengal, the productivity is the lowest (585.83 kg ha^{-1})

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(Bureau of Applied Economics and Statistics, 2016). The low productivity of green gram is associated with the infestation of a wide array of lepidopteran insect pests leading to complete crop loss. Those insect pests are also associated with black gram too which leads to a reduction of production per unit area (Ghosal *et al.,* 2018).

Technology interventions in relation to plant health management are an important area to augment yield by suppressing the pest population through different technologies like host plant interaction alteration, and physiological aspect management involving integrated pest management (IPM) based plant health management module application implicating low pesticide usage. In the present experiment, the impact of different key eco-friendly plant health management technologies on production and pest management in mustard and two popular pulse crops (black gram and green gram) in South 24 Parganas district were studied.

MATERIALS AND METHODS

On-farm trials were conducted in the farmers' fields of Baruipur (Ghola and Moutala villages) and Basanti (Nafargaunj, Uttar Sonakhali and Narayantala villages) blocks of South 24 Parganas district, West Bengal during 2017-18 and 2018-19 to study the impact of crop-specific technologies and organic growth stimulants on mustard, black gram and green gram crops. Seven farmers for each of the crops (mustard, black gram and green gram) were selected for conducting the trials on the basis of a pre-scheduled questionnaire-based pilot study. The selected farmers were trained through training and method demonstration. Mustard variety NC-1 (*Jhumka*) was cultivated with the recommended package of practices during the *rabi* season. Seeds @ 5 kg ha^{-1} were sown on 1st November at a row-to-row distance of 30-40 cm and a plant-to-plant distance of 10-15 cm. The crop was fertilized with the recommended dose of fertilizer (100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1}). Half of the total N and full doses of P and K were broadcasted during final land preparation. Rest half of N was top-dressed at 20-25 days after the emergence of seedlings. Thinning was done at 25-30 DAS to maintain proper plant-to-plant spacing as per recommendations. Further, one hoeing was done to promote plant growth. Black gram (var. WBU-108) and green gram (var. IPM 2-3) were cultivated in pre-kharif and summer seasons, respectively. Black gram and green gram were cultivated through broadcasting with a seed rate of 30 kg ha^{-1} and maintaining the plant population of 35 plants and 55 plants m^{-2}, respectively, by thinning at 20 DAS. In both the pulse crops, phosphorus @ 40 kg ha^{-1} was applied during final land preparation and 2% boron was sprayed at the flowering stage. Except for treatments or technology options, no other plant health management techniques were adopted during the crop growth period for all three crops under study.

In the case of mustard, the experimental setup was organised with two technologies *i.e.*, installation of bee box @ 3 ha^{-1} of *Apis mellifera* (TO-1) and installation of *Apis cerena indica* bee box @ 5 ha^{-1} (TO-II) along with farmers' practice (natural/open pollination) in seven different farmer's fields in the villages of Ghola and Moutala in the Baruipur block. Each experimental field was more than 1 km apart from the other to reduce the cross-pollination of one site with another (considering the 1 km radius of the bees' hovering area). The evaluation of bio-stimulant-based practices on black gram was carried out in seven different farmer's fields in the Ghola and Moutala villages of Baruipur block, and Uttar Sonakhali in Basanti block while in green gram crop the study was conducted in Nafargaunj, Uttar Sonakhali and Narayantala villages of Basanti block. Two different technology options, as well as a farmer practice replicated in the seven selected farmer fields, were evaluated during the study.In black gram, technology option I (TO-I) consisted of the application of *beejamrit* (5 kg cow dung + 5 L cow urine + 50 g lime mixed with 20 L water and handful soil fermented overnight for 100 kg seed) for seed bio-priming and 5% *jeevamrit* (10 kg cow dung + 10 L cow urine + 2 kg molasses +1 kg pulse powder mixed and fermented for 7 days) at 30 and 45 DAS as spray and soil application @ 600 L ha^{-1} and technology option II (TO-II) consisted of spraying of *panchagavya* @ 5% (7 days fermented mixture of cow dung, cow urine, milk, curd, ghee at 5:3:2:2:1 ratio), *sasyagavya* @ 5% (7 days fermented product of cow dung, cow urine, vegetable waste at 1:1:1 with twice amount of water) and *dasaparni* @ 1% (7 days fermented product of ten different leaves having alkaloids mixed with 5 times cow urine) at 30 DAS onwards at 15 days interval in alternate with 600 L ha^{-1} *jeevamrit* as soil application at 30 DAS.

The technologies evaluated for green gram consisted of the application of *T. viride* enriched cow dung @ 750 kg ha^{-1}, seed treatment with carboxin 17.5 % + thiram 17.5 % @ 3 mL kg^{-1} seed, installation of pheromone trap @ 30 $bigha^{-1}$ and need-based spot application of *neemastra* @ 3% (5 kg neem leaves ground to a paste + 10 L water + 5 L cow urine + 1 kg cow dung fermented for 7 days) (TO-I) and chemical management (TO-II) which involved two round spraying of beta cyfluthrin + imidacloprid 300 OD (8.49% + 19.81% w/w) @ 0.4 g L^{-1} and thiodicarb 75WP @ 1.25 g L^{-1} at 30 DAS onwards at 15 days interval.

All the technologies were evaluated against the farming practices being followed by the seven selected farmers for each crop under the study. The performance of the technologies for the given crops was assessed with performance indicators like yield and yield attributing characters, pest incidence and economic returnswhich are presented as pooled data for the two experimental years.The test for comparison of the data was done following the standard statistical analysis procedure in a randomised block design (RBD) at 5% level of significance (Gomezand Gomez, 1984).

RESULTS AND DISCUSSION

Impact of crop-specific technologies

The impact of crop-specific technologies on the response of the three crops, *viz.*, mustard, black gram and green gram in comparison to the farmer's practice are presented and discussed below.

Mustard

Among the various pollinating agents, insects play a major role in pollination. Of the total pollination activities, over 80% is performed by insects (Robinson and Morse, 1989) and bees contribute nearly 80% of the total insect pollination and are considered the best pollinators due to their suitable body size, hairiness, thoroughness, steadfastness, floral constancy, and manageable populations. Planned crop pollination is considered to be the most important input because of yield optimizing benefits. Thus, bee pollination plays an important role in increasing the yield of rapeseed mustard. The data presented in Table 1 revealed that the installation of bee hive in the mustard field increased the yield to the tune of 46.59% on an average (53.53% potential yield increase was noted with the installation of mellifera bee hive @ 3 ha^{-1}; whereas it was 39.65% in case of cerena type @ 5 ha^{-1}). The difference in mustard yield among the bee types (TO-I and TO-II) was, however, not significant. Installation of bee hives did not influencethe vegetative growth parameters of the plant like plant height and the number of primary and secondary branches. Maximum number of pods $plant^{-1}$, pod length, pod setting (%), number of seeds pod^{-1}, thousand seed weight and seed yield $plant^{-1}$ was noticed with the installation of *A. mellifera* bee hives. Increased pod setting by 30.17% and 20.90% was also recorded with bee hive installation of *A. mellifera* (TO-I) and *A. cerena indica* (TO-II), respectively (Table 1) over the control. Interestingly, it was also observed that the aphid incidence was also less in both cases where bee hives were installed. Visit of bees may interfere with the incidence of aphids due to their buzzing sound and the lowest infestation of aphids was noticed where bee hives were installed (Fig.1). Additional income of ₹ 9600 and ₹ 4520 was achieved through bee hive installation in respect of *A. mellifera* and *A. cerena* types of bees from 1 ha of land, respectively (Table 2).

From the present study, it was observed that crop-specific technologies like the installation of bee hives in the mustard field increased the yield of mustard and similar results have also been reported in the studies conducted by Bhowmik *et al.* (2014) and Nagpal *et al.* (2017). Designed crop pollination strategies were found to be preferred and effective strategies with respect to other input-use-based crop productivity enhancement strategies. Bee pollination-based mustard farming helped in yield optimization *vis-a-vis* minimum environmental disruptions with sustainable impact. The bowl-shaped flower of mustard helps in the landing of pollinators, especially honey bees. Hossain *et al.*(2020) reported that honey bees enhanced the pollination of the

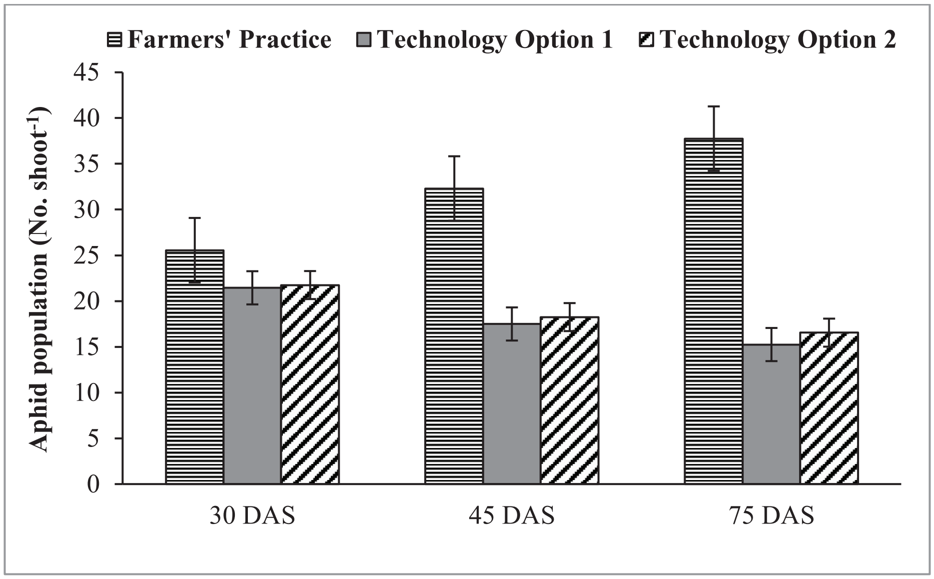

Fig. 1. *Infestation levels of aphid in mustard*

mustard plant and netting with honey bees increased the mean seed yield per plant of mustard by 15%, however, there was a decrease in the period of flowering. The mustard yield was considerably higher in honey bee foraging plots. While Patidar *et al.* (2017) found that yield of mustard is highest in open pollinated conditions followed by bee hive based pollination. Additional farmyard pollination benefit due to bee hive installation was also reported by Khalifa *et al.* (2021).

Black gram

It is prominent from the present study (Table 3) that spraying of *panchagavya* (5%), *sasyagavya* (5%) and *dasaparni* (1%) at 30 DAS onwards at 15 days intervals in alternate with 600 L ha^{-1} *jeevamrit* (TO-II) as soil application at 30 DAS resulted in highest grain yield (0.95 t ha^{-1}) followed by application of *beejamrit* for seed bio-priming and 5% *jeevamrit* at 30 and 45 DAS as spray and soil application @ 600 L ha^{-1} (TO-I). Though both the technologies demonstrated were at par with each other in terms of crop yield, the yield attributing characters were boosted through the application of the biostimulants in both the selected technology options. The highest number of pods per plant (34.05) and length of pods (8.45 cm) was recorded with TO-II followed by TO-I. Pod setting was also influenced by the application of organic bio-stimulants (70.01 and 68.90, respectively in TB-II and TB-I) (Table 3). Maximum haulm yield was also achieved by TB-II (2.52 t ha^{-1}) followed by TO-I (2.50 t ha^{-1}) and farmers' practice (FP) (2.45 t ha^{-1}) (Table 3). Infestation of pod borer per 10 plants (12.71), infested pod (8.6%), per cent wilt (6.98) and per cent powdery mildew incidence (21.2) were lowest in TO-II followed by TO-I and FP (Table 4). Higher benefit cost ratio was also obtained with TO-I and TO-II as compared to farmer's practice (Table 5).

Green gram

Lepidopteran insect pests are one of the main constraints in green gram cultivation, of which *Spodoptera litura* and *Helicoverpa armigera* are considered to be the major insect pests. It was observed that low productivity of this crop is associated with low seed rate, low input use along with the adoption of improper management of pest incidence. Besides, it was also observed that the productivity gap can be minimised by the adoption of proper technology interventions like the application of *T. viride* enriched cow dung @ 750 kg ha^{-1}, seed treatment with carboxin 17.5% + thiram 17.5% @ 3 mL kg^{-1} seed, installation of pheromone trap @ 30 ha^{-1}, need based spot application of *neemastra* @ 3% (TO-I). The highest yield (Table 6) was achieved in TO-I (0.94 t ha^{-1}) followed by TO-II (0.93 t ha^{-1}) and FP (0.78 t ha^{-1}). The height of the plant was significantly higher than that of chemical treatment while all other growth characteristics were significantly higher in both the demonstrated technologies compared to the farmers' practice. The seed and husk ratio was found to be higher

Table 1. *Impact of different technology options on growth, yield components and yield of mustard (Poole data)*

Technology Option	Plant height (cm)	No. of primary branches plant^{-1}	No. of secondary branches plant^{-1}	No. of siliqua plant^{-1}	No. of seeds siliqua^{-1}	Pod setting (%)	Length of siliqua (cm)	Test weight (g)	Seed yield (t ha^{-1})
FP	133.75	4.20	8.75	162.30	9.45	65.55	7.50	3.66	0.75
TO-I	132.90	4.15	8.90	219.50	11.45	85.33	9.10	4.11	1.15
TO-II	133.50	4.21	8.55	210.75	10.35	79.25	8.55	3.91	1.05
$CD_{0.05}$	NS	NS	NS	2.11	0.042	0.039	0.026	0.041	0.12

NS - non-significant

Table 2. *Economic assessment of mustard cultivation with different technology options (Pooled data)*

Technology option	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
FP	15650	27713	12063	1.77
TO-I	17650	42550	24900	2.41
TO-II	17550	38702	21152	2.20

B:C ratio - Benefit: cost ratio; *Selling price - ₹ 37.00/- kg^{-1}

Table 3. *Impact of different technology options on growth, yield components and yield in black gram (Pooled data)*

Technology Option	Plant height (cm)	Pod setting (%)	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	Length of pod (cm)	Test weight (g)	Seed yield ($t\ ha^{-1}$)	Haulm yield ($t\ ha^{-1}$)
FP	35.45	58.60	22.25	9.50	7.55	3.21	0.73	2.45
TO-I	42.05	68.90	32.75	10.25	8.33	3.26	0.92	2.50
TO-II	44.25	70.01	34.05	10.55	8.45	3.33	0.95	2.52
$CD_{0.05}$	1.46	1.98	1.62	0.75	0.49	NS	0.10	0.07

NS - non-significant

Table 4. *Impact of different technology options on pest incidence in blackgram (Pooled data)*

Technology Option	No. of pod borer 10 $plants^{-1}$			Mean	Infested pod (%)		Mean	Wilt (%)		Mean	Powdery mildew (%)		Mean
	30 DAS	45 DAS	75 DAS		45 DAS	75 DAS		30 DAS	45 DAS		45 DAS	60 DAS	
FP	19.33	21.45	20.75	20.51	12.33	14.50	13.41	7.79	9.45	8.62	35.05	42.20	38.62
TO-I	15.45	15.25	14.25	14.98	9.10	11.05	10.07	6.60	7.33	6.96	21.30	27.25	24.27
TO-II	12.75	13.05	12.33	12.71	7.75	9.45	8.6	6.96	7.01	6.98	19.65	22.75	21.20
$CD_{0.05}$	0.23	0.26	0.19		0.16	0.19		NS	0.09		1.01	2.09	

DAS - days after sowing; NS - non-significant

Table 5. *Economic assessment of black gram cultivation with different technology options (Pooled data)*

Technology option	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
FP	17045	32625	15580	1.91
TO-I	17250	41400	24150	2.40
TO-II	17375	42525	25150	2.44

B:C ratio - Benefit: cost ratio; *Selling price - ₹ 45/- kg^{-1}

Table 6. *Impact of different technology options on growth, yield components and yield of green gram (Pooled data)*

Technology Option	Plant height (cm)	Root length (cm)	Pod setting (%)	No. of pods plant^{-1}	No. of seeds plant^{-1}	Length of pod (cm)	Test weight (g)	Seed yield (t ha^{-1})	Seed:husk
FP	25.42	5.68	63.55	11.08	7.25	6.50	3.72	0.78	1.83
TO-I	35.56	7.63	72.30	21.33	10.65	7.62	3.83	0.94	2.10
TO-II	31.72	6.89	69.25	19.45	9.80	7.55	3.81	0.93	2.02
$CD_{0.05}$	3.09	1.92	2.33	2.07	1.87	1.04	NS	0.19	0.09

NS - non-significant

Table 7. *Impact of different technology options on pest incidence in green gram (Pooled data)*

Technology Option	No. of *Spodoptera* 10 plants^{-1}			Mean	No. of spotted pod borer 10 plants^{-1}			Mean	No. of blue butterfly 10 plants^{-1}			Mean	Infested pod (%)		Mean
	30 DAS	45 DAS	75 DAS		30 DAS	45 DAS	75 DAS		30 DAS	45 DAS	75 DAS		45 DAS	75 DAS	
FP	29.25	72.68	43.10	48.34	6.33	9.45	9.01	8.26	2.33	1.20	1.75	1.76	12.75	26.78	19.77
TO-I	16.75	21.45	22.50	20.23	7.50	10.30	9.90	9.23	4.01	3.30	3.25	3.52	09.50	16.45	12.98
TO-II	32.05	9.26	4.25	15.19	6.20	2.35	1.50	3.35	2.25	0	0	0.75	6.25	9.50	7.88
$CD_{0.05}$	3.03	2.69	1.88		NS	1.74	2.65		0.53	0.29	0.32		1.34	2.71	

DAS - days after sowing; NS - non-significant

Table 8. *Economic assessment of green gram cultivation with different technology options (Pooled data)*

Technology option	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
FP	13280	39000	25720	2.93
TO-I	13890	47050	33160	3.38
TO-II	14420	46600	32180	3.23

B:C ratio - Benefit: cost ratio; *Selling price ₹ 50/- kg^{-1}

in both TO-I (2.1) and TO-II (2.0). *Spodoptera*, spotted pod borer and blue butterfly were found to infest the pods. It was observed that TO-II which comprised of new generation chemicals exerted better results (7.88% pod infestation) in managing the lepidopteran pests, while TO-I was also found to be quite effective against those pests (12.98%). The mean *Spodoptera* population was recorded to the tune of 20.23 nos. 10 plants^{-1} in TO-I in comparison to that of 48.34 nos. 10 plants^{-1} in FP. The lowest population of different pod infesting borer pests was recorded in TO-II (Table 7). Highest B:C ratio (3.38) was also recorded with the adoption of TO-1 (Table 8).

The present findings indicated that organic biostimulants like *panchagavya, jeevamrit, beejamrit, sasyagavya, neemastra* and *dasaparni* influenced the plant health providing better nourishment to crops. These biostimulants helped to boost the growth of the plant by enhancing the organic carbon level in the soil and better microbial activity (Ghosal, 2021) *vis-a-vis* reduced the pest load following the techniques of antixenosis (Ghosal *et al.,* 2021). Kumari *et al.* (2019) reported maximum N, P and K contents in soil following the application of *vermicompost* @ 8 t ha^{-1} + *Jeevamrut* (Drenching @ 5%). The feeding deterrent and antifeedant effect of these biostimulants was also reported by Ghosal *et al.* (2021). As organic bio-stimulants are a rich source of microbiome thus their application enhances the diversity and functions of root microbiomes. Ram *et al.* (2018) isolated several isolates of beneficial microbes from panchagavya among which *Pseudomonas, Rhizobium, Azotobacter* and *Azospirillum* were predominant. They also reported that *panchagavya* was rated the most effective bio-enhancer followed by biodynamic liquid pesticides, *jeevamrita* and *amritpani.* Ghosal and Sahu (2018), Nitin and Purohit (2021) and Somasundaram *et al.* (2003) also reported that bio-stimulants could play the role of a persuasive source of beneficial microbes that boost plant immunity, improve soil fertility and enhance crop productivity and produce quality. Ghosal *et al.* (2022) reported that 75% organic and 25% innovative management through bio-stimulant enhances the arthropod community in soil. They act as bio-enhancers cum bio-pesticides improving the plant health and thus conferring host plant resistance. The effect of different organic biostimulants on pest incidence boosted through host plant resistance was also suggested by Ghosal *et al.* (2021).

It is apparent from the present findings that crop-specific technology interventions can effectively be utilized to boost the yield potentiality of the crops. As bees are frequent visitors to the mustard fields, enhanced pollination can be achieved through bee hive installation. The present finding suggests that the installation of *Apis cerena indica* (Indian bee) can be utilized to increase the yield of mustard as it does not require migration and the farmers can easily manage the hives with low maintenance costs. Organic biostimulants like *panchagavya, sasyagavya, jeevamrit, beejamrit, dasaparni* and *neemastra* can effectively boost plant health, which is reflected with higher yield in the case of green gram and black gram. These organic biostimulants are also very much effective to reduce the pest load due to their antifeedant and repellent action.

CONFLICTS OF INTEREST

The authors have no conflict of interest.

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