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Mustard variety CS-58 & role of halo mix on crop productivity under problematic soils (salt stress) in U.P. and yield gap analysis

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Abstract
The Impact of microbial bio-formulation on mustard crop productivity during *Rabi*, 2020-21 to 2022-23 under demonstration in saline-sodic soils of Sultanpur was assessed. A total of 275 clients on Integrated Crop Management (ICM) in mustard with salt tolerant variety CS 58 and the use of bio-formulation (PSB) were undertaken in 50.0 ha area at 45 villages of Motigarpur, Jaisinghpur and Kadipur Blocks of district. Salt tolerant variety CS-58 is recommended for saline soil up to soil salinity level (EC) 12.0 dSm-1 and in alkali soils up to pH 9.5. as it is highly suitable for saline and sodic soil conditions. Based on three years data, It may be concluded that the improved practice (IP) had an average seed yield of 21.18q. ha^{-1}, which enhance yield up to 20.37% from the farmer's practice about 17.64 q. ha^{-1}. The average extension gap, technology gap and technology index were 253.33 kg ha^{-1}, 382.33 kg ha^{-1}, and 15.72%, respectively. The economic analysis of demonstrations revealed the viability of enhanced technology, with a net return of 88575.67 Rs. ha^{-1} and benefit-cost ratio (BCR) of 5.82, compared to 72327.33 Rs. ha^{-1} and 5.37 (BCR) farmers practice. The cultivation of salt tolerant variety of mustard are practiced in salt affected areas of U.P.

Keywords: Salinity, sodicity, impact, mustard, net return, gap analysis

Introduction
At present, India has 6.73 million ha salt-affected area, of which 2.95 million ha is distributed over 16 states. Major salt affected areas are Gujarat, Uttar Pradesh, Maharashtra, Tamil Nadu, Haryana and Punjab states that account for 80% of the total sodic lands of India (Wicke *et al*., 2012).
In India 75% of the saline and sodic soil is observed in states of Gujarat (2.23 m ha), Uttar Pradesh (1.37 m ha), Maharashtra (0.61 m ha), West Bengal (0.44m ha) and Rajasthan (0.38 m ha). The quality of water in these regions are also found to be marginal (Singh, 2009).
In Uttar Pradesh soil degradation due to salinization is considered a major constraint for agricultural productivity. In irrigated areas, the formation of salt-affected soils is the most important process of land degradation. Land degradation occurs through the poor quality of water on the agricultural land. Salt-affected soils occur most often in arid and semiarid climates but they can also be found in areas where the climate and mobility of salts cause saline waters and soils for short periods of time (Tanji, 1990). There is a need for reclamation the sodic soils to improve the crop productivity and soil fertility and in the mean time there is also a need of salt tolerant varieties to survive in the salt affected areas to improve the existing yield.
Rapeseed (Brassica campestris) and Mustard (Brassica juncea) are the major rabi oilseed crops of India. India is one of the largest producer of these crops in the world. The production of rapeseed and mustard in India accounts for about 18% of the total oilseed production of the country. Mustard occupies an area of 6.78 million hectare with production and productivity 9.12 million tons and 1345 kg ha^{-1}, respectively in India. Rajasthan, Haryana, Uttar Pradesh and Madhya Pradesh, West Bengal and Gujarat are the major producers of mustard in the country. In India, rapeseed and mustard comes under major edible oilseeds which is consumed as culinary purpose, The seed and oil are used as condiment in the preparation of pickles and for flavouring curries and vegetables. The oil is utilized for human consumption throughout northern India in cooking and frying purposes. The oil cake is used as a cattle feed and manure. Green stems and leaves are a good source of green fodder for cattle. The leaves of young plants are used as green vegetables as they supply enough sulphur and minerals in the diet. The oil content of the rapeseed and mustard ranges from 30 to 48 percent.
Poor adoption of high yielding varieties, improved package of practices and lack of suitable plant protection measures found as major extension gap which is negatively impacts the productivity of mustard in the region. Among the insect-pests (aphid, mustard saw fly, painted bug), diseases (Alternaria blight, white rust) and weeds considered major biotic factors for lower yield of this crop.
Government of India took initiative towards the self-dependency of country in edible oils and launched various schemes through ICAR and SAUs to quick and effective transfer of improved technology of oilseed crops at farmer's fields. KVK's role in agriculture and its related sectors is critical because it is well positioned to spread field-tested proven technologies with suitable modulation that meet location-specific challenges and concerns about current natural and socio–economic conditions, requirements, and

priorities. In light of the foregoing, the demonstration on mustard employing latest high yielding crop variety, sulphur-based fertilisers and newer plant protection measures was initiated with the aim of exhibiting the productive potential of new production technologies in a real set of situations over a locally cultivated practice. Keeping this in view, present demonstration were organized in participatory mode with the objective to enhance production potential of mustard crop in the sub-tropical region of Uttar-Pradesh.

Materials and Methods

The current study was carried out by Department of Soil Science & Agricultural Chemistry, Kamla Nehru Institute of Physical and Social Sciences, Sultanpur, Uttar Pradesh, India & ICAR-CSSRI, Krishi Vigyan Kendra, Hardoi-II at the farmers' fields of various villages in the Sultanpur district Uttar Pradesh for three years, from *Rabi* 2020-21 to *Rabi* 2022-23, in different villages of different three Blocks of Sultanpur district. On improved mustard cultivation practices, a total of 278 demonstrations with high yielding variety (CS 58) and full package of practices were held across 50-hectare area in various places. Table 1 lists the materials or practices used in demonstrations and farmers' practice. it is recommended for saline soil up to soil salinity level (EC) up to 12.0 dSm-1 and in alkali soils up to pH 9.5 and a sandy to sandy loam texture having low to medium levels of important micronutrients and organic carbon.

Every year, the sowing took place in mid to last september under irrigated condition and the harvest took place in the first fortnight of March to third week of March. Farmers received key inputs such as seed, fertiliser and need-based plant protection chemicals as listed in table 1. Frequently visit by scientists and teaching staff to the demonstration fields ensured that the farmers received correct direction. Farmers who were chosen for demonstration were taught and given thorough information on how to grow mustard successfully using the suggested package of methods. Whereas, farmers were allowed to do their own practices in case of farmer’s practice or local practices. Field days and farmer meetings were held to allow other farmers to see the advantages of the varieties and technology that had been exhibited. The data on different parameters like seed yield and percent insect-pest incidence were collected separately from both improved (IP) and farmer’s practice (FP) for comparative analysis.

Table 1: Particulars showing the details of mustard cultivation practices under demonstration and existing practices

S. No.	Operation	Farmer’s practice	Demonstration
1.	Seed & seed rate	Use of old variety (Kranti & Varuna) with high seed rate @5-6 kg/ha	CS 58 (CS-58, it is recommended for saline soil up to soil salinity level (EC) up to 12.0 dSm-1 and in alkali soils up to pH 9.8) with seed rate@4-5kg/ha
2.	Seed treatment	Generally, not practiced	Carbendazim @2.8g/ per kg seed or Metalaxyl @5.5g/per kg before one day sowing followed by *Trichoderma viridae* @ 12g/kg seed
3.	Sowing time	05 Oct. to 25th December.	5th September to 15st December.
4.	Sowing method	Broad casting	Line sowing: R x P = 45 x 30cm & broadcasting
5.	Manure & Fertilizers	FYM: None 100:80: 0 (N: P: K, kg/ha)	FYM: 10-15 t/ha 80: 46: 30:50 (N: P: K:S, kg/ha) & 400 kg Gypsum/ha
6.	Irrigation	2-5 irrigations	1-3 irrigations
7.	Weed management	One hand weeding at 25-30 DAS	Pre-emergence uses of Pendimethalin @3.0 kg/ha
8.	Plant protection	No	▪ Two foliar spray of Neem oil 3000 ppm @ 80 ml/15 litre water, followed by Thiamethoxam 30 FS @ 6.8g/15 litre water for the control of aphid in late sowing. ▪ One spray of carbendazim 50 WP @ 2.9g/litre water to manage the Alternaria blight and white rust diseases
9.	Bioformulation (Halo CRD & Halo mix)	No	Yes

Further, data tabulated and analysed by using statistical tools like frequency and percentage. The gross returns, net returns, benefit cost ratio (BCR), extension gap, technology gap, and technology index were worked out using the Samui *et al.* (2000) [11] equations.

Technology gap = Potential yield - Demonstration yield

Extension gap = Demonstration yield - yield under existing practice

Technology index (%) = [(Potential yield - Demonstration yield)/Potential yield] x 100

Additional Return = Demonstration Return – Farmers’ Practice Return

Net returns = Total (Gross) Returns – Total Cost of Production

Benefit Cost Ratio (BCR) = Gross Return /Gross Cost

Results and Discussion

Impact of microbial bio-formulation on yield:

Impact of bio-formulation and variety on yield of mustard on demonstration and local farmers practice showed in Table 2 that the average seed yield was significantly higher (20.37%) with an additional yield obtained 354kg ha^{-1}in CFLD plots where average mustard yield was 2118 kg ha^{-1}in comparison to local check (1764 kg ha^{-1}) during the study period. During *Rabi* season 2020-21, 2021-22, and 2022-23, the average seed yield recorded under improved practice (IP) was 1954, 2134 and 2265 kg ha^{-1}, compared to farmer's practice (FP) where it was obtained 1548, 1850 and 1895 kg ha^{-1}, respectively. The similar trends of yield enhancement in frontline demonstration on mustard and other oilseeds reportedby Lathwal *et al.* (2010) [7]; Katare*et al.* (2011) [17]; Tiwari *et al.* (2017) [19]; Ghintala*et al.* (2018) [4]; Kumar *et al.* (2019) [6] and Sharma *et al.* (2020) [13].

Table 2: Year wise details and impact of halophilic microbial bio-formulation on yield (Average of three years)

Year	No. of Demo	Area (ha)	Potential yield (kg/ha)	Demo (IP)* yeild (kg/ha)	Local (FP)*Yield (kg/ha)	% yeild increased over FP
2020-21	10	5.0	2500	1954	1548	26.23
2021-22	150	20.0	2500	2134	1850	15.35
2022-23	115	25.0	2500	2265	1895	19.52

*IP=Improved Practice; FP= Farmers Practice

Increased awareness and acceptance of the whole package of practices, including timely sowing, line sowing, use of prescribed fertiliser doses, thinning, better weed control, and need-based plant protection measures, may explain the higher yield in demonstration plots.

Technological gap analysis in Yield

Technology gap:

The average technology gap was observed as 382.33kg*/ha* as the difference between potential yield and demonstration plots yield was higher i.e., 546kg/ha during the year 2020-21 followed by 366 kg and 235*/ha* in 2021-22 and 2022-23, respectively (table 3), therefore, It showed that still there is gap in technology demonstration plot as a result of which the potential yield of the improved practices could not be reaped by the participating farmers. The technology gap observed may be attributed to dissimilarity in the fertile condition of soil, agronomical practices and weather condition. The findings are in line with that reported by Vijaya Lakshmi *et al.* (2017) and Singh, *et al.,* 2019 [16].

Extensions gap

The difference between demonstrated yield and yield under existing farmers practice is extension gap. The extensions gap were observed higher 406 kg/ha in 2020-21 followed by 370 kg/ha and 284kg/ha in 2022-23 and 2021-22, respectively during demonstration period (Table 3). The average extension gap was observed as 353.33 kg/ha in this finding and it may be over bridged by various extension methods like maximum use of the latest improved technologies with high yielding varieties of oilseed crops. The demonstrations can help in adoption of improved production and protection technology. This finding is in corroboration with the findings of Singh, *et al.,* (2019) [16].

Technology index

The ratio between technology gap and potential yield expressed as percentage is technology index. The acceptability and practically of demonstrated technology are always inversely related to technology index, with higher adoptability of technology resulting in lower technology index value. Moreover, the data showed that the technology index was lowest (10.68 percent) in 2022-23, and greatest (21.84 percent) in 2020-21, with an average of 15.72 percent. The value of technology index indicates that the applied technique was widely accepted and viable by farmers. This variation indicates that the result differs according soil fertility status, weather condition and mismanagement of crop. With adoption of improved practices, the technology gap can be reduced as a result technology index will be reduced. Similar findings were reported by Singh, *et al.,* 2019 [16].

Singh *et al.* (2008) [15], Singh *et al.* (2019) [16]; Patel *et al.* (2009) [10]; Singh and Sharma (2016) [14]; Kalita *et al.* (2019) [5] and others have reported on the impact of FLDs on various crops.

Table 3: Extension gap, technology gap and technology index of mustard under CFLDs

Year	Extension Gap ($kgha^{-1}$)	Technology Gap ($kgha^{-1}$)	Technology Index (%)
2020-21	406	546	21.84
2021-22	284	366	14.64
2022-23	370	235	10.68
Mean	353.33	382.33	15.72

Impact of microbial bio-formulation on economic:

The impact of microbial bio-formulation on the economics can be significant. PSB-microorganisms are adapted to high-salt environments and have potential applications in agriculture, bioremediation, and industrial processes.

In agriculture, the use of PSB microbial bio-formulations can improve soil fertility and crop productivity in saline-affected areas. This can lead to increased agricultural output and potentially boost the local economy by providing more food resources or enhancing cash crops.

Additionally, this bio-formulations may contribute to sustainable agricultural practices by reducing the need for chemical fertilizers and mitigating soil salinity issues, which could result in cost savings for farmers.

The primary necessity of a newer technology exhibited on farmers' fields to assess the profit over existing technology is economic viability. The cost of mustard cultivation and production data were gathered and analysed for gross return (Rs. ha^{-1}), net return (Rs ha^{-1}), additional income (Rs ha^{-1}), and benefit cost ratio in cluster frontline demonstrations. The results of the mustard cultivation economic analysis (Table-4) revealed that enhanced technology yielded a greater average gross return of Rs. 92725 ha^{-1} over the study period than farmer's practice (Rs. 77206 ha^{-1}).

Table 4: Impact of PSB Microbial Bio-formulation on Economic analysis of demonstrations on Mustard- 2020-2023

Year	Gross cost (Rs. /ha)		Gross Return (Rs. /ha)		Net Return (Rs. /ha)		Additional Return (Rs. /ha)	B:C Ratio	
	IP*	FP	IP	FP	IP	FP		IP	FP
2020-21	17300	15450	98677	78174	81377	62724	18653	5.70	5.06
2021-22	18500	16450	107767	93425	89267	76975	12292	5.82	5.68
2022-23	19300	17800	114383	95697	95083	77283	17800	5.93	5.38
Mean	18366.67	16566.67	106942.33	89098.67	88575.67	72327.33	16248.33	5.82	5.37

*IP=Improved Practice; FP= Farmers Practice

Furthermore, the higher net returns of Rs. 65000, 53500, 63945, 42130, and Rs. 84800 ha^{-1} from demonstration plots compared to farmer's practice of Rs. 38000, 46160, 54780, 34940, and Rs. 71280 ha^{-1} for the years 2016-17, 2017-18, 2018-19, 2019-20, and 2020-21, respectively, with an increased average net return of Rs. 61875 ha^{-1} from improved practice over Rs. 49032 ha^{-1} recorded in local check. Under the illustrated plot, an average benefit cost ratio of 3.09 was found, which was greater than conventional practice (2.75). The impact of presented technique was proved by the average increased return of Rs. 13143 ha^{-1} acquired in terms of extra input cost of Rs. 2676 ha^{-1}. The findings of the economic study clearly showed that the exhibited technology is more profitable and economically viable. These findings are in conformity with those of Naveen *et al.* (2017) [9]; Kumar *et al.* (2018); Kalita *et al.* (2019) [5]; Sangwan *et al.* (2021) [12] and Tetarwal and Singh (2021) [18].

Fig 1: Demonstration on Mustard with bioformulations (halo-mix) to alleviate salt stress at Sultanpur

Fig 2: Demonstration on Mustard with bioformulations (halo-mix) to alleviate salt stress at Hardoi

Conclusion

Based on the results of a three-year impact study of demonstrations, it may be concluded that mustard crop productivity and economic returns can be increased by using a high-yielding salt tolerant variety, an improved package of practices, balanced fertilisation, appropriate plant protection measures and use of bioformulations. The higher net return and benefit cost ratio indicated the demonstrations economic feasibility and assured farmers that the KVK's and KNIPSS intervention would be adopted. According to the findings, demonstration programmes were extremely efficient in encouraging and altering the attitudes of other farmers toward the adoption of high-yielding varieties and superior cultivation methods. As a result, enhanced technology must be disseminated through large-scale demonstrations and awareness programmes with line departments in order to close the adoption gap (extension gap, technology gap) and raise farmer income. Soil amelioration observed during crop periods due to gypsum and sulphur application in mustard. The cultivation of salt tolerant variety of mustard (CS-52, CS-54, CS-56, CS-58, CS-60,) are practiced in salt affected areas of U.P., this varieties improved soil health.

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