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Effect of biofertilizers and potassium on growth and yield of yellow mustard (*Brassica campestris* L.)

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Abstract
A field experiment was conducted during *Rabi*, 2021 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P). The experiment was laid out in Randomized Block Design with the combination of Biofertilizers (*Azotobacter* and PSB) and different levels of Potassium (35,40 and 45 kg/ha). Totally there were nine treatments which were replicated thrice. The results revealed that significantly higher plant height (129.83 cm) at harvest and dry weight (9.10 g) at 60 DAS recorded with the treatment Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8). Whereas maximum Crop growth rate (8.30 g/m^2/day) at 60 DAS was recorded with the treatment PSB at 20 g/kg seed + K at 40 kg/ha (T_5) and Relative growth rate (0.0333 g/g/day) at 60 DAS was recorded with the treatment Azotobacter at 20 g/kg seed + K at 35 kg/ha (T_1). Yield attributes *viz*. Number of siliqua per plant (134.53), seeds per siliqua (31.67), test weight (3.40 g), seed yield (1.53 t/ha), stover yield (5.20 t/ha) and harvest index (22.74%) were recorded maximum with the treatment *Azotobacter* at 10 g/kg seed + PSB at 10 g/kg seed + Potassium at 40 kg/ha (T_8).

Keywords: *Azotobacter, PSB*, potassium, growth, yield, yellow mustard

Introduction
Yellow Mustard (*Brassica campestris* L.) or *Brassica hirta* or *Sinapsis alba* is a very important good oilseed crop among the rapeseed and mustard group in terms of high oil and protein content. It is also called as white mustard or safed rai in hindi which belongs to the family Cruciferae and genus Brassica and it has an eminent place among all oilseed crops next to groundnut (Verma *et al*. 2018) [22]. It is the 2nd prominent oil-yielding crop among the Brassica family after Indian mustard (*Brassica juncea* L.) followed by toria (*Brassica campestris* var. toria) which contain a chemical named as "Sinalbin". It is originated from the European temperate region. Mustard oil is used as condiment in pickles, flavouring curries and vegetables, preparation of hair oils, medicines, soap making and in the tanning industry for softening of leather. The mustard cake is used mostly for cattle feed and manure (Potdar *et al*. 2019) [15]. In the tropics, it is normally mixed cropped with gram, wheat and lentils mostly in the rabi seasons (Chauhan *et al*. 2020) [24]. The estimated area, production and yield of rapeseed-mustard in the world was 36.59 million hectares, 72.37 million tonnes and 1980 kg/ha, respectively, during 2018-19. Globally, India account for 19.8% and 9.8% of the total acreage and production (USDA).

Biofertilizer are known to play a number of vital roles in soil fertility, crop productivity and production in agriculture as they are eco- friendly but cannot at any cost replaces chemical fertilizers that are indispensable for getting maximum crop yields. They contain microorganisms which are capable of mobilizing nutrient elements from unavailable form to available form through different biological processes (Hadiyal *et al*. 2017) [8]. Long-term addition of organic materials to soil resulted as an increase in organic matter, crop productivity and soil biological activity (Collins *et al*. 1992) [2]. Azotobacter inoculants when applied to many non-leguminous crop plants, promote seed germination and initial vigour of plants by producing growth promoting substance (Kalita *et al*. 2019) [9]. *Azotobacter* inoculation improves the crop productivity by 0-25% over the control in the absence of any amendment and by 8.75% in the presence of NPK (Narula 2000) [13]. Phosphate solubilizing bacteria (PSB) promote seed germination and initial vigour of the plants by producing growth promoting substances. Application of PSB results in increased mineral and water uptake, root development, vegetative growth and phosphorus fixation (Gangwal *et al*. 2011) [5]. PSB solubilizes unavailable phosphorus in soil and makes it available to the plants.

In recent years, potassium deficiency has been aggravated in the soil due to continuous crop removal and use of potassium analysis NPK fertilizers. Leaching and erosion losses also contribute to potassium deficiencies tends to affect adversely the growth and yield of seed crop, which reduces the crop yield to an extent of 10-30%. For oilseeds, potassium are most vital nutrients for the growth and development of mustard crop. Besides N and P. the use of K has been reported to influence the productivity of seed yield and seed oil contents (Ghosh *et al*. 1995) [6] Potassium nutrition is associated with grain quality including protein content Potassium stimulates the transport of nitrogenous compounds to developing fruits and thereby increase seed yield.

Materials and Methods

A field experiment was conducted during *Rabi*, 2021, at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj. The soil was sandy loam in texture, low in organic carbon and medium in available nitrogen, phosphorous, and low in potassium. The experiment was laid out in Randomized Block Design comprising of 9 treatments which are replicated thrice. Each treatment net plot size is 3m × 3m. The treatments are categorized with recommended dose of nitrogen through urea and Phosphorous through SSP, in addition Potash through Muriate of Potash were applied in combinations and Biofertilizers were applied as per the treatment details. The sowing was done on 20th October 2021 with the seed rate of 4 kg/ha. The factors used are Bio fertilizers (*Azotobacter* and *PSB*) and Potassium levels (35, 40 and 45 kg/ha). The treatment details are as follows, T_1-*Azotobacter* at 20 g/kg seed + Potassium at 35 kg/ha, T_2-*Azotobacter* at 20 g/kg seed + Potassium at 40 kg/ha, T_3-*Azotobacter* at 20 g/kg seed + Potassium at 45 kg/ha, T_4- PSB at 20 g/kg seed + Potassium at 35 kg/ha, T_5-PSB at 20 g/kg seed + Potassium at 40 kg/ha, T_6-PSB at 20 g/kg seed + Potassium at 45 kg/ha, T_7-*Azotobacter* at 10g/kg seed + PSB at 10g/kg seed + Potassium at 35 kg/ha, T_8- *Azotobacter* at 10g/kg seed + PSB at 10g/kg seed + Potassium at 40 kg/ha and T_9-*Azotobacter* at 10g/kg seed + PSB at 10g/kg seed + Potassium at 45 kg/ha. The crop was harvested treatment wise at harvesting maturity stage. Growth parameters *viz*. plant height (cm), dry weight (g/plant) were recorded manually on five randomly selected representative plants from each plot of each replication separately and after harvesting, number of siliqua/plant, seeds/plant, test weight, seed yield and stover yield were calculated from each net plot and was computed and expressed in tonnes per hectare. The data was computed and analysed by following statistical method of Gomez and Gomez (1984) [7].

Results and Discussion

Effect on the growth of yellow mustard: It is evident from Table-1 Plant height was recorded significantly higher at harvest with the application of Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8) (129.83 cm). However, the treatments Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 35 kg/ha (T_7) (128.97 cm) and Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 45 kg/ha (T_9) (129.20 cm) were statistically at par with treatment Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8). Dry weight at 60 DAS was recorded significantly higher with the application of Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8) (9.10 g). However, the treatments Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 35 kg/ha (T_7) (8.90 g) and Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 45 kg/ha (T_9) (9.00 g) were statistically at par with treatment Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8). During 60-80 DAS, treatment with PSB at 20 g/kg seed + K at 40 kg/ha (T_5) was recorded highest Crop growth rate (8.30 g/m^2/day) and there was no significant difference among the treatments. During 60-80 DAS, treatment with *Azotobacter* at 20 g/kg seed + K at 35 kg/ha (T_1) recorded highest Relative growth rate (0.0333 g/g/day) and there was no significant difference among the treatments. Increase in Plant height due to *Azotobacter* which has the ability to fix nitrogen, produce plant growth promoting antifungal and antibacterial substances which influence plant growth favorably. Whereas, PSB improved the plant growth which might be due to solubilizing of native P by phosphate-solubilizing microorganisms through production of organic acids like glutamic, succinic, lactic, oxalic, glyoxylic, malic, fumaric, tartaric, propionic and formic acid (Mir *et al.* 2004) [12]. The increase in plant height might be due to the Potassium in that application plays a crucial role in meristematic growth through its effect on the synthesis of Phyto hormones. Among various plant hormones, cytokinin plays an important role in growth of the plant. Beneficial effect of K on growth reported by Farhad *et al.* (2010) [4]. The higher crop growth rate among the biofertilizers might be due to higher dry matter accumulation. Since the CGR is a function of total dry matter production (Pramanik and Bera, 2013) [16]. This result is in full agreement with Shinde (1990). The reason for obtaining higher relative growth rate may be due to increase in cell multiplication, cell elongation and cell expansion throughout the entire period of crop. This might be resulted in higher production of photo synthetics and their translocation to sink, which ultimately increased the plant growths (Meena *et al.* 2018) [11].

Effect on the yield of yellow mustard: The Yield and Yield parameters of yellow mustard were tabulated in Table 2 shows that Maximum number of Siliqua/plant (134.53) were recorded with the treatment *Azotobacter* at 10g/kg seed + PSB at 10 g/kg seed+ K at 40 kg/ha (T_8) which was superior over rest of all treatments. However, treatments with Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 35 kg/ha (T_7) (132.80) and Azotobacter at 10g/kg seed + PSB at 10 g/kg seed + K at 45 kg/ha (T_9) (133.40) were statistically at par with treatment Azotobacter at 10g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8). Maximum Number of seeds/siliqua (31.67) were recorded with the treatment Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8) which was superior over rest of all treatments. However, treatments with PSB at 20 g/kg seed+ K at 45 kg/ha (T_6) (30.80) and Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 45 kg/ha (T_9) (31.20) were statistically at par with treatment Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8). Maximum Test weight (3.40 g) was recorded with the treatment Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8) which was superior over rest of all treatments. However, treatments with Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 35 kg/ha (T_7) (3.27 g) and Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 45 kg/ha (T_9) (3.33 g) were statistically at par with the treatment Azotobacter at 10 g/kg seed+ PSB at 10 g/kg seed + K at 40 kg/ha (T_8). Seed yield (1.53 t/ha) was recorded significantly highest with treatment Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8) which was superior over rest of all treatments. However, treatments with *Azotobacter* at 10g/kg seed+ PSB at 10 g/kg seed + K at 35 kg/ha (T_7) (1.51 t/ha) and *Azotobacter* at 10g/kg seed+ PSB at 10 g/kg seed + K at 45 kg/ha (T_9) (1.52 t/ha) were statistically at par with treatment Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8). Stover yield (5.20 t/ha) was recorded significantly highest with treatment Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8) which was superior over rest of all treatments. However, treatments with *Azotobacter* at 10 g/kg seed + PSB at 10 g/kg seed + K at 35 kg/ha (T_7) (4.98 t/ha) and *Azotobacter* at 10 g/kg seed + PSB at 10 g/kg seed + K at 45 kg/ha (T_9) (5.18 t/ha) were statistically at par with treatment Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8). Harvest index (22.74%) was recorded highest with the treatment Azotobacter at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha (T_8) and there was no significant difference among the treatments. The significant increase in number of siliqua and grains/siliqua is due to increase in the availability of Nitrogen through bio fertilizer inoculation by which more siliqua lets are produced due to increased rates of siliqua lets primordial production, similar results were found Hadiyal *et al*. (2017) [8]. This might be due to the fact that *Azotobacter* inoculation fixed atmospheric nitrogen into soil asymbiotically results into better root development and more nutrient availability, resulted in better flowering and siliqua formation and ultimately beneficial effect on seed yield. There were to be a positive synergistic effect that caused to improving photosynthesis by increasing water and nutrients absorption and thus leading to more assimilate and improving plant growth, as result number of siliquae/plant and 1,000 seed weight may have increased as compared with *Azotobacter*, PSB + *Azotobacter* inoculation. Similar result was reported by (Pramanik and Bera, 2013) [16] and Patra *et al*. 2013 [14]. Potassium application enhances the development of strong cell walls and improves germination of pollen in the florets which leads to high fertility and Siliqua formation. The results were in accordance with Cheema *et al.* (2012) [1]. Potassium might be attributed to better filling of grains and thus, an increase in different yield attributing characters. The results were found to be similar with Singh *et al.* (2017) [17]. Increase in yield through bio-fertilizer might be attributed to supply of more plant hormones (auxin, cytokinin, gibberellin etc.) by the microorganisms inoculated or by the root resulting from reaction to microbial population similar results were obtained by Kalita *et al.* (2019) [9]. Potassium application stimulates the cumulative effect of improvement in yield attributes *viz.* number of siliqua per plant, no of seeds per siliqua and test weight and also increased availability, absorption, and translocation of K nutrient which helped in higher seed yield. The results were in accordance with Singh *et al.* (2017) [17]. With the increment in supply of essential nutrient to rapeseed-mustard, their availability, acquisition, mobilization and influx into the plant tissues increased and thus improved growth attributes, yield components and finally yield. These results are in agreement with the findings of Dutta and Singh (2002) [3], Singh and Sinsinwar (2006) [18]; Tripathi *et al*. (2010) [19].

Table 1: Effect of Biofertilizers and Potassium on Growth Parameters in Yellow mustard.

S. No	Treatment Combinations	Plant height (cm)	60 DAS Dry weight(g)	60 DAS Crop Growth Rate ($g/m^2/day$)	Relative Growth Rate (g/g/day)
1.	*Azotobacter* at 20g/kg seed + K at 35 kg/ha	124.33	7.40	7.78	0.0333
2.	*Azotobacter* at 20g/kg seed+ K at 40 kg/ha	126.77	8.03	7.96	0.0319
3.	*Azotobacter* at 20g/kg seed+ K at 45 kg/ha	125.93	7.80	7.89	0.0323
4.	PSB at 20 g/kg seed+ K at 35 kg/ha	127.30	8.10	8.22	0.0324
5.	PSB at 20 g/kg seed+ K at 40 kg/ha	128.57	8.43	8.30	0.0317
6.	PSB at 20 g/kg seed+ K at 45 kg/ha	127.77	8.40	8.11	0.0313
7.	*Azotobacter* at 10g/kg seed + PSB at 10 g/kg seed+ K at 35 kg/ha	128.97	8.90	8.11	0.0299
8.	*Azotobacter* at 10g/kg seed+ PSB at 10 g/kg seed+ K at 40 kg/ha	129.83	9.10	8.26	0.0298
9.	*Azotobacter* at 10g/kg seed + PSB at 10 g/kg seed+ K at 45 kg/ha	129.20	9.00	8.15	0.0298
	F-test	S	S	NS	NS
	SEm (±)	0.35	0.09	0.17	0.0007
	CD (P= 0.05)	1.06	0.26	--	--

Table 2: Effect of Biofertilizers and Potassium on yield attributes in yellow mustard.

S. No.	Treatment Combinations	No. of siliqua/ plant	No. of Seeds/ siliqua	Test weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
1.	*Azotobacter* at 20 g/kg seed + K at 35 kg/ha	125.80	29.27	2.63	1.29	4.52	22.29
2.	*Azotobacter* at 20 g/kg seed + K at 40 kg/ha	127.20	29.87	2.83	1.39	5.06	21.57
3.	*Azotobacter* at 20 g/kg seed+ K at 45 kg/ha	126.87	29.87	2.77	1.36	5.02	21.32
4.	PSB at 20 g/kg seed+ K at 35 kg/ha	129.27	30.00	2.87	1.40	4.22	21.58
5.	PSB at 20 g/kg seed+ K at 40 kg/ha	131.80	30.20	3.07	1.48	4.39	22.03
6.	PSB at 20 g/kg seed+ K at 45 kg/ha	130.80	30.80	2.97	1.42	4.34	21.84
7.	*Azotobacter* at 10 g/kg seed + PSB at 10 g/kg seed + K at 35 kg/ha	132.80	30.27	3.27	1.51	4.98	22.10
8.	*Azotobacter* at 10 g/kg seed + PSB at 10 g/kg seed + K at 40 kg/ha	134.53	31.67	3.40	1.53	5.20	22.74
9.	*Azotobacter* at 10 g/kg seed + PSB at 10 g/kg seed + K at 45 kg/ha	133.40	31.20	3.33	1.52	5.18	21.75
	F-Test	S	S	S	S	S	NS
	SEm (±)	0.67	0.31	0.06	0.01	0.14	0.55
	CD (P=0.05)	2.02	0.92	0.17	0.03	0.42	--

Conclusion
Based on the findings of the investigation it may be concluded that treatment with *Azotobacter* at 10g/kg seed+ PSB at 10 g/kg seed+ K at 40 kg/ha performed well exceptionally in all growth and yield parameters and in obtaining maximum seed yield of yellow mustard. Hence, *Azotobacter* at 10 g/kg seed+ PSB at 10 g/kg seed+ K at 40 kg/ha may be more preferable and can be recommended.

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