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Effect of Potassium on the Growth and Yield of Different Varieties of Mustard (*Brassica juncea L.*) under Poplar (*Populus deltoides*) Based Agroforestry System

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted to find out the "Effect of potassium on the growth and yield of different varieties of Mustard (*Brassica juncea L.*) under Poplar (*Populus deltoides*) based agroforestry system" at Forestry Nursery, the research farm of the College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, U.P., India. Experiment was laid out in randomized block design with 3 different varieties of Mustard viz. T59-Varuna, Pioneer 45s 42s, and Jugni in 3 replications and 5 levels of Potassium per variety (50%

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kg/ha), (75% kg/ha), (100% kg/ha), (125% kg/ha) and (150% kg/ha) as of total 15 treatments in all. The result shows that the application of increased levels of potassium fertilizers showed high growth and yield of Mustard. It was recorded from the application of potassium fertilizers in treatments applied with (MOP @ 150% kg/ha) resulted in increased pre-harvest observation viz., plant height (cm), dry weight (g/plant), crop growth rate (g/m^2/day) and increased relative growth rate (g/g/day). It was also concluded from the trail that the application of fertilizers in treatment with (MOP @ 150% kg/ha) was found in increasing post-harvest observations viz., number of siliqua/plants, number of seeds/siliquas, test weight (g), seed yield (t/ha), stover yield (t/ha), harvest index (%). Also, after the economic analysis, the returns as compared to investment were found to be more profitable.

Keywords: Potassium; mustard; varieties; poplar; agroforestry.

1. INTRODUCTION

The term “Agroforestry” refers broadly to land-use systems where woody perennials, such as trees, shrubs, or bamboos, are produced and utilised in fields and farming landscapes. This can be done simultaneously, as in intercropping systems where crops and trees are planted side by side, or intermittently, as in rotational practices.

A study by [1] discussed the role of agroforestry in mitigating climate change, highlighting how trees in agroforestry systems can sequester carbon from the atmosphere and reduce greenhouse gas emissions. The study also discussed the potential for agroforestry to provide adaptive capacity in the face of climate change, through the diversification of crops and the provision of ecosystem services such as shade and wind protection. In addition, a study by [2] reviewed the potential of agroforestry in achieving the Sustainable Development Goals (SDGs), showing how agroforestry can contribute to multiple SDGs such as poverty alleviation, food security, and climate action. These studies demonstrate the potential benefits of agroforestry as a sustainable land use system that can provide a range of environmental, economic, and social benefits. As such, agroforestry is an important approach to achieving sustainable development and mitigating the impacts of climate change.

Populous deltoides is a member of the Salicaceae family, also referred to as Poplar or eastern cotton wood. Poplars are soft-wooded trees with a rapid growth rate that can reach heights of 30 metres and girths of 2 metres. They have an open crown with a few wide branches and a very straight, thin trunk. A review by [3] discusses the potential benefits of alley cropping systems, which include planting crops between rows of Poplar trees. The authors suggest that these systems can improve soil fertility and water availability, which can lead to increased crop growth and yield.

Mustard (*Brassica juncea* L.) Mustard has been a traditionally important oilseed crop in India. It is a major Rabi crops, Mustard is cultivated in mostly under temperate climates between October-November and February-March. As a cold-weather crop, it is also produced in several tropical and subtropical areas. Dry matter is a crucial factor in crop development and yield, and changing management practises like sowing dates and soil fertility management under a changing environment have a significant impact on this parameter [4]. The ideal way to maximise the accumulation of dry matter, provide the most conducive conditions for maximum light absorption, and maximise the use of moisture and nutrients for improved plant growth and seed output is to sow at the right time [5].

Rapeseed is an important oilseed crop that is grown globally for its seeds, which are used for oil production and animal feed. To achieve high yields and improve the quality of the seeds, farmers often use inorganic fertilizers. Inorganic fertilizers are made up of synthetic compounds that provide essential nutrients such as nitrogen, phosphorus, and potassium, which are essential for plant growth and development. A study conducted in China found that the application of nitrogen fertilizer significantly increased the yield and oil content of rapeseed crops [6]. Another study in France found that the application of phosphorus fertilizer increased the yield of rapeseed crops, but did not have a significant effect on oil content [7]. Inorganic fertilizers can also be used more efficiently through the adoption of precision agriculture practices that help farmers apply the right amount of fertilizer at the right time and place [8].

Potassium is one of the essential nutrients which is needed for the growth and development of plants. Potassium nutrition is associated with seed quality, including protein content and also stimulates the transport of nitrogenous compounds to developing fruits and thereby increasing seed yield. As low soil K status is an important limiting factor responsible for poor yields of the crops, it is imperative to evaluate the response of K nutrition on Mustard productivity. Also in case of 2:1 type of clay in vertisols the availability of potassium is low though soils are rich in potassium due to potassium fixation in this type of clays. Leaching and erosion losses also contribute to nutrient deficiencies. Decline in crop yield due to lack of K supply was reported even in K rich soils like vertisols [9].

2. MATERIALS AND METHODS

The research was carried out in the College of Forestry's research nursery during 2022 in Sam Higginbottom University of Agriculture, Technology, and Science, Prayagraj. Prayagraj city is located in the subtropical belt of India's south-east at 25.28 N latitude and 81.54 E longitude, at an elevation of 98 m above mean sea level. Temperatures in the atmosphere range from 4°C or less in the winter to 46°C in the summer. The average annual rainfall is 1100 mm.

Experiment was laid out in randomized block design with 3 different varieties of Mustard viz. T59-Varuna, Pioneer 45s 42s and Jugni in 3 replications and 5 levels of Potassium (MOP) per variety (50% kg ha), (75% kg ha), (100% kg/ha), (125% kg/ha) and (150% kg/ha) as of total 15 treatments in all. Mustard seed were sown at spacing of 40 x 20 cm in the experimental field on 3rd November 2022 during *Rabi* season. The parameters were calculated at different intervals such as 30 DAS, 60 DAS, 90 DAS and at time of Harvest (120 DAS). The crop was harvested manually with the help of sticks from each plot when nearly 90% pods matured. Harvested crop was left in the field for sun drying two days and weight of air-dried bio-mass (seed and stover) per plot was recorded before threshing.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height (cm)

At 120 DAS the significantly and higher plant height was observed in treatment T_{15} (176.07 cm) at the rate of 150% MOP kg/ha. However, T_{10} (173.76 cm) and T_5 (173.75 cm) were statistically at par to T_{15} (176.07 cm). Higher levels of potassium resulted in improved growth, with increased plant height, leaf area, and biomass accumulation observed [10].

3.1.2 Dry weight (g/plant)

At 120 DAS the highest dry weight was observed in T_{15} (19.81 g) at the rate of 150% MOP kg/ha. However, T_{10} (19.57 g) and T_5 (19.26 g) were statistically at par to T_{15} (19.81 g). Higher levels of potassium resulted in improved growth, with increased plant height, leaf area, and biomass accumulation observed [10].

3.2 Yield Parameters

3.2.1 Number of siliqua/plants

At 120 DAS the highest Number of siliqua per plant observed in treatment T_{15} (200.47) at the rate of 150% MOP kg/ha. Application of Potassium had increased siliqua per plant due to might be higher soil organic matter improving soil structure and maximized microbial activities [11].

3.2.2 Number of seeds per siliqua

At 120 DAS the highest the Number of seeds per siliqua observed in treatment T_{15} (24.18) at the rate of 150% MOP kg/ha. The plants treated with elevated potassium levels exhibited improved vegetative growth compared to those with lower potassium supply [11].

3.2.3 Seed yield (t/ha)

At 120 DAS the maximum seed yield (t/ha) was observed in treatment T_{15} (1.88 t/ha) at the rate of 150% MOP kg/ha. However, T_{10} (1.85 t/ha) and T_5 (1.82 t/ha) were statistically at par to T_{15} (1.88 t/ha). Higher levels of potassium application resulted in increased plant height, more branches, higher pod numbers, and improved seed yield in Mustard plants [12].

3.2.4 Stover yield (t/ha)

At 120 DAS the maximum stover yield (t/ha) was observed in treatment T_{15} (3.27 t/ha) at the rate of 150% MOP kg/ha. However, T_{10} (3.23 t/ha) and T_5 (3.17 t/ha) were statistically at par to T_{15} (3.27 t/ha). Increase in growth, yield characters and finally crop yield could be ascribed to the overall improvement in plant growth, vigour and production of sufficient photosynthesis through increased leaf area, the increase in grain yields might be due to adequate quantities and balanced proportions of plant nutrients supplied to the crop as per need during the growth period resulting in favourable increase in yield attributing characters which ultimately led towards an increase in economical yield [13].

3.2.5 Harvest index (%)

At 120 DAS the highest harvest index (%) was observed in treatment T_{15} (36.51%) at the rate of 150% MOP kg/ha. However, T_{10} (36.43) and T_5 (36.41) were statistically at par to T_{15} (36.51%). Adequate potassium supply can contribute to

Table 1. Effect of different varieties and fertilizers on growth parameters of mustard (*Brassica juncea L.*) under poplar (*Populus deltoides*) based agroforestry system

Treatments	Treatment Details	Growth Parameters			
		Plant height (cm)	Dry weight (g)	CGR ($g/m^2/day$)	RGR (g/g/day)
T1	T59 VARUNA + 50%	153.87	15.15	0.73	0.00475
T2	T59 VARUNA + 75%	159.51	16.30	0.78	0.00468
T3	T59 VARUNA + 100%	165.78	17.17	0.73	0.00414
T4	T59 VARUNA + 125%	167.00	18.26	0.74	0.00389
T5	T59 VARUNA + 150%	173.75	19.26	0.76	0.00377
T6	PIONEER 45s 42s + 50%	155.27	15.57	0.76	0.00482
T7	PIONEER 45s 42s + 75%	162.96	16.53	0.76	0.00443
T8	PIONEER 45s 42s + 100%	166.76	17.59	0.78	0.00426
T9	PIONEER 45s 42s + 125%	172.14	18.57	0.75	0.00389
T10	PIONEER 45s 42s + 150%	173.76	19.57	0.78	0.00382
T11	JUGNI + 50%	155.48	15.75	0.70	0.00434
T12	JUGNI + 75%	164.79	16.79	0.73	0.00420
T13	JUGNI + 100%	169.41	17.89	0.78	0.00423
T14	JUGNI + 125%	173.10	18.87	0.75	0.00381
T15	JUGNI + 150%	176.07	19.81	0.74	0.00380
	F-test	S	S	NS	S
	SEm±	4.94	0.66	0.03	0.00019
	CD (p=0.05)	14.32	1.92	-	0.00056

Table 2. Effect of different varieties and fertilizers on siliquas and seed content of mustard (*Brassica juncea L.*) under poplar (*Populus deltoides*) based agroforestry system

Treatments	Treatment Details	Yield	
		No. of Siliqua/plant	No. of Seeds/Siliqua
T1	T59 VARUNA + 50%	150.33	19.14
T2	T59 VARUNA + 75%	159.61	20.26
T3	T59 VARUNA + 100%	173.56	21.24
T4	T59 VARUNA + 125%	182.52	22.26
T5	T59 VARUNA + 150%	191.62	23.23
T6	PIONEER 45s 42s + 50%	152.51	19.56
T7	PIONEER 45s 42s + 75%	163.53	20.61
T8	PIONEER 45s 42s + 100%	176.57	21.57
T9	PIONEER 45s 42s + 125%	185.51	22.54
T10	PIONEER 45s 42s + 150%	196.42	23.56
T11	JUGNI + 50%	157.61	19.87
T12	JUGNI + 75%	168.54	20.81
T13	JUGNI + 100%	179.58	21.85
T14	JUGNI + 125%	188.53	22.85
T15	JUGNI + 150%	200.47	24.18
	F-test	NS	S
	SEm±	7.13	0.63
	CD (p=0.05)	-	1.81

increased seed or fruit yield in Mustard crops. Potassium plays a role in the development and quality of reproductive structures, sufficient potassium levels can enhance reproductive processes. Furthermore, the study reveals the influence of potassium and biofertilizer on Mustard crop quality. The plants treated with the combination of potassium and biofertilizer exhibited higher oil content, protein content, and other quality parameters in Mustard seeds, indicating improved nutritional value and quality attributes, resulting in better seed or fruit production and higher harvest index [14].

3.3 Economics

Economics analysis of all treatments were calculated according to expenditure incurred from the land preparation till harvesting of the crop. Gross return (t/ha), Net return (t/ha), Cost

Table 3. Effect of different varieties and fertilizers on yield parameters of mustard (*Brassica juncea L.*) under poplar (*Populus deltoides*) based agroforestry system

Treatments	Treatment Details	Yield Parameters			
		Test weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
T1	T59 VARUNA + 50%	2.02	1.27	2.47	33.98
T2	T59 VARUNA + 75%	2.78	1.46	2.72	34.94
T3	T59 VARUNA + 100%	3.21	1.58	2.92	35.22
T4	T59 VARUNA + 125%	3.72	1.72	3.05	36.04
T5	T59 VARUNA + 150%	4.54	1.82	3.17	36.49
T6	PIONEER 45s 42s + 50%	2.29	1.37	2.56	34.84
T7	PIONEER 45s 42s + 75%	2.98	1.52	2.78	35.35
T8	PIONEER 45s 42s + 100%	3.37	1.63	2.96	35.49
T9	PIONEER 45s 42s + 125%	3.99	1.75	3.08	36.24
T10	PIONEER 45s 42s + 150%	4.76	1.85	3.23	36.43
T11	JUGNI + 50%	2.54	1.42	2.66	34.81
T12	JUGNI + 75%	3.06	1.55	2.84	35.32
T13	JUGNI + 100%	3.56	1.67	3.02	35.66
T14	JUGNI + 125%	4.15	1.78	3.14	36.21
T15	JUGNI + 150%	4.96	1.88	3.27	36.51
	F-test	S	S	S	S
	SEm±	0.26	0.75	0.89	0.60
	CD (p=0.05)	0.76	2.18	2.60	1.75

Table 4. Effect of different varieties and fertilizers on economic analysis of mustard (*Brassica juncea L.*) under poplar (*Populus deltoides*) based agroforestry system

Treatments	Treatment details	Economics (INR/ha)			
		Cost of cultivation	Gross return	Net return	Benefit cost ratio (B:C)
T1	T59 VARUNA + 50%	25220	77513.76	52293.76	2.07
T2	T59 VARUNA + 75%	25445	88584.21	63139.21	2.48
T3	T59 VARUNA + 100%	25670	95858.75	70188.75	2.73
T4	T59 VARUNA + 125%	25895	103269.57	77374.57	2.98
T5	T59 VARUNA + 150%	26120	109100.43	82980.43	3.17
T6	PIONEER 45s 42s + 50%	26780	`82908.05	56128.05	2.09
T7	PIONEER 45s 42s + 75%	27005	91744.32	64739.32	2.39
T8	PIONEER 45s 42s + 100%	27230	98330.02	71100.02	2.61
T9	PIONEER 45s 42s + 125%	27455	105065.60	77610.60	2.82
T10	PIONEER 45s 42s + 150%	27680	110732.94	83052.94	3.00
T11	JUGNI + 50%	25805	86010.39	60205.39	2.33
T12	JUGNI + 75%	26030	93812.53	67782.53	2.60
T13	JUGNI + 100%	26255	100853.83	74598.83	2.84
T14	JUGNI + 125%	26480	107007.70	80527.70	3.04
T15	JUGNI + 150%	26705	112763.63	86058.63	3.22

of Cultivation (INR/ha) were calculated and found to be more profitable in treatment given at MOP @ 150% kg/ha as compared to other levels of treatments and the lowest value was observed in treatment given at MOP @ 50% kg/ha.

4. CONCLUSION

On the basis of trail, it has been founded that the highest growth and yield have been seen in T_{15}: (MOP @ 150% kg/ha) found superior in all the aspects Plant height (cm), Dry weight (g), Number of siliquas, Number of seeds per siliqua, Grain yield (t/ha), Stover yield (t/ha), Harvest index (%). While the minimum was found from $T_{1:}$ (MOP @ 50% kg/ha). However, since this is based on one season experiment, further trials may be needed to substantiate the results. Based on trial, the economic analysis revealed that the maximum profits in terms of Benefit cost ratio was obtained from T_{15} (1:3.22) while minimum profit is obtained in T_1 (1:2.07) under Poplar based Agroforestry system.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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