

Impact of Integrated nutrient management on growth and yield characteristics of mustard (*Brassica juncea* L.)

Abstract

The experiment was conducted at the Instructional Farm (SIF) of Chandra Shekhar Azad University of Agriculture and Technology in Kanpur, Uttar Pradesh in the *Rabi* season of 2023-24. A Randomized Block Design was used for statistical analysis, with 10 treatments and 3 replications. The primary objectives of this study involved assessing the crop growth and yield attributes, in mustard crops subjected to different treatments. These treatments consisted of various chemical fertilizers, bio fertilizers, and nanofertilizers used in different combinations. Results revealed that effect of treatment T10 [Nano DAP @ 40 ppm + RD of N & K (120:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹] was found best in terms of growth and yield attributes of crop, whereas minimum growth and yield attributes of crop was found under the effect of treatment T5 [Nano urea @ 60 ppm + RD of P & K (60:60)].

1. Introduction: It is crucial for Indian agriculture to become more knowledge intensive to effectively address the challenges posed by a growing population, limited land availability, and diminishing energy resources (Swaminathan and Bhavani, 2013). The group of oilseed crops has a significant impact on India's agrarian economy, with a total yield of 22.1 million tonnes from an area of 25.4 million hectares. India holds the impressive position of being the fourth largest oilseed economy globally, following the U.S., China, and Brazil. Additionally, it stands as the second largest importer, just behind China. According to Jha *et al.*, (2012), this country contributes significantly to the global oilseeds area, vegetable oils production, and total edible oils consumption. Oilseeds have a significant presence in the country's agricultural landscape, accounting for 13% of the gross cropped area. They also make a valuable contribution to the Gross National Productivity (GNP), representing about 5% of it. Additionally, oil seeds contribute 10% of the overall value of agricultural products in the country (DOA & FW, 2022).

Mustard, scientifically known as *Brassica juncea* (L.), is a significant oil seed crop that falls under the family "Cruciferae." According to a study by Bhowmik *et al.* (2014), the oil content in mustard seeds can range from 37-49 percent. These seeds are known for their high nutritional value, containing 38-57% erucic acid and 27% oleic acid. The oil cake residue is commonly used as cattle feed and fertilizer, with a nutrient composition of 5.1% nitrogen (N), 1.8% phosphorus pentoxide (P₂O₅), and 1.1% potassium oxide (K₂O). According to Mukherjee (2010), this crop has the potential to be grown in the winter (*Rabi*) season because it can adapt well and make use of leftover moisture. The protein content of mustard seed is approximately 30-45%,

making it a highly nutritious food. Theseed and oil have various culinary uses, such as being used as a condiment in pickles andfor adding flavor to curries and vegetables. The oil is commonly used for cooking andfrying in northern India. Additionally, it finds application in the formulation of hair oil,pharmaceuticals, and the production of greases. This substance is commonly employed inthe production of soap and is also utilized in combination with mineral oils to provide lubrication.Theoilcakesserveadualpurpose,functioningasbothcattlefeedandmanure.Greenstemsandleavesprovideanutritioussourceoffodderforcattle. Mustardoiliscommonly utilized in the tanning industry to effectively soften leather, as noted by **SinghandSingh (2001)**.

Mustardsisasignificantoilseedcrop.However,itsproductivityinthestatefallsshortofitsfullpotential.Toenhanceits yield,acombinationofbalancedfertilizationand effective management practices is necessary. The role of nutrients in supporting plantgrowth and development cannot be overstated. They play a vital role in facilitating

cellgrowth,cellenlargement,andnutrienttransportationthroughoutdifferentpartsoftheplant.Themustardplanthasa greaterdemandformacro-nutrients,suchasnitrogen,phosphorus,and potassium, in comparison to other nutrients. Understanding the importance of macro-nutrients is essential for assessing the fruit yield and quality of the citrus plant (**Albrigo,2002**). Nano-fertilizers have been developed to carefully release nutrients in a controlledmanner, perfectly matching the specific requirements of the crop. The controlled releasemechanismensuresthatthereisnoprematureinteractionwiththesoil,waterenvironment,ormicroorganisms. Asaresult,theplantsystemefficientlyabsorbsthenutrientsoncetheyare released. According to **De la Rosa et al. (2013)**, these unique characteristics canimprovethe crop's nutrient use efficiency. Extensive use of chemical fertilisers has had negative consequences on soil quality,health, and productivity, as well as the pollution of surface and groundwater sources**Hazarika et al., (2011)**.

Bio-fertilizersarespecializedformulationsthatharnessthepowerofmicro-organismstoconvertnutrientsfromtheirnon-usablestateintoaformthatcanbereadily absorbed by plants. This transformation occurs through a natural biological process. Bio-fertilizers have been shown to enhance both the quantity and quality of various plants.According to a study conducted by **Yosefiet al. (2011)**, the combination of bio-fertilizersandchemicalfertilizershasbeenfoundtoenhancecropproductivityandimprovenutrientuseefficiency.

Bio fertilizers have proven to be highlyeffective in producing impressive results when compared to chemical fertilizers. This isbecause each gram of carrier for bio fertilizers contains a minimum of 10 million viablecells of a specific strain (**Anandaraj and Delapierre, 2010**). In non-leguminous crops, biofertilizers like Azotobacter play a crucial role asnitrogen-fixing bacteria. Azotobacter has been found to enhance plant growth and increasecrop yield in various soil conditions (**Okon and Gonzalez, 1994**). The bacteria is Gram-negativeandexhibitspolymorphism,withvaryingsizesandshapes.Thesizeofthesecellscanvary,typicallymeasurin

between 2-10 x 1-2.5 µm. Mustard is a crucial oilseed crop that holds great economic importance. It is vital to optimize its production in order to ensure food security and support livelihoods in various regions.

2. Method and Materials:

The experiment was conducted at Instructional Farm (SIF), Chandra Shekhar Azad University of Agriculture and Technology in Kanpur served as the experimental site. Kanpur Nagar is a city in central Uttar Pradesh that is at a height of 125.9 meters above sea level on the alluvial tract of the Gangetic plains. Its coordinates are 25° to 28° North latitude and 79° to 80° East longitude. This semi-arid climate and rich alluvial soil characterize this northern zone. About 935 mm of rain falls on the region each year on average. Relative humidity (7 am) is relatively constant at about 80-90% from July to the end of March, gradually declines to about 40-50% by the end of April, and remains at 80% until June, even though temperatures in May and June can reach 44°C to 47°C or higher.

Edaphic condition: Soil samples were collected from different locations of the field before sowing and analysed some physio-chemical characteristics in the Laboratory, C.S. Azad University of Agriculture and Technology, Kanpur. The available Nitrogen in soil was 189.12 kg ha⁻¹, which was estimated by the Alkaline permanganate method given by **Subbiah and Asija**, the available Phosphorus was 14.60 kg ha⁻¹ estimated by Olsen's method given by **Olsen et al.**, (1954). The available K was 167.31 kg ha⁻¹ which was estimated by the Flame photometer method given by Black, 1965. The available S was 18.50 kg ha⁻¹ which was estimated by the calcium extraction method given by **William and Steinberg**. The soil of the experimental field was clayey in texture and slightly alkaline in pH (8.12) estimate Glass Electrode, pH Meter given by **Piper (1950)**. The electrical conductivity (EC) of the soil was 0.39 (d S m⁻¹) estimated **Method No. 4, USDA Handbook by Piper (1950)**. Organic carbon in the soil was 0.42% which was estimated by rapid titration method given by **Walkley and Black**.

Treatment details: The experiment was laid out in Randomized Block Design with three replications. There were fourteen treatment combinations (**T₁**) RDF(120:60:60) + Sulphur @ 25 kg ha⁻¹, (**T₂**) RDF(120:60:60) + Azotobacter @ 2 kg ha⁻¹, (**T₃**) RDF(120:60:60) + PSB @ 4 kg ha⁻¹, (**T₄**) RDF(120:60:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹, (**T₅**) Nanourea @ 60 ppm + RD of P&K (60:60), (**T₆**) NanoDAP @ 40 ppm + RD of N&K (120:60), (**T₇**) Nanourea @ 60 ppm + RD of P&K (60:60) + Azotobacter @ 2 kg ha⁻¹, (**T₈**) Nanourea @ 60 ppm + RD of P&K (60:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹, (**T₉**) NanoDAP @ 40 ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha⁻¹, (**T₁₀**) NanoDAP @ 40 ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹.

Seed and Sowing: The necessary amount of seed is measured and planted in the furrows. The furrows were created at a row distance of 30 cm and a depth of 3.0-3.5 cm using the desi Plough. The recommended seed dosage of 5 kg per hectare was used for sowing.

Manure and fertilizer application: In the experimental field, well decomposed farmyard manure (FYM) at a

rate

of

2.4 tons per hectare, as well as vermicompost at a rate of 6 tons per hectare, was applied using the broadcasting method in each plot. These fertilizers were applied at different rates, as per the treatment of the recommended dose of NPKS (120:60:60:25 kg ha⁻¹). The remaining nitrogen was applied as top dressing in two separate split doses. The first top dressing was applied after 35 days after sowing (DAS), followed by the second application at 50 DAS. Application on nano Urea and nano DAP was done according to the treatment combinations 30 and 60 days after sowing.

Biofertilizer application: Biofertilizers Azotobacter and PSB were given by soil method @ 2 kg ha⁻¹ and 4 kg ha⁻¹ respectively by mixing with the organic manures before sowing of seeds.

3. Results and Discussion

1. Plant Population

The analysis of effect of various treatments has been thoroughly examined and the results have been presented in Table 1. Upon examining the table, it becomes evident that the various treatment combinations had no significant impact on the plant population (plants m⁻²). At 20 days after sowing (DAS) effect of treatments T5 [Nano urea @ 60 ppm + RD of P&K (60:60)] and T6 [Nano DAP @ 40 ppm + RD of N&K (120:60)] were found to be highest with 11.11 plants m⁻² area whereas least plant population of 10.97 plants m⁻² was found under the effect of treatment T3 [RDF (120:60:60) + PSB @ 4 kg ha⁻¹]. Also, at harvest, effect of treatment T10 [Nano DAP @ 40 ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹] was found to be highest with 11.08 plants m⁻² area whereas least plant population of 10.3 plants per m² was found under the effect of treatment T5 [Nano urea @ 60 ppm + RD of P&K (60:60)].

3.2. Plant height (cm)

According to the Table no. 1 data pertaining to plant height (cm) of mustard (*Brassica juncea* L.) at 30, 60, 90 and at harvest, it was revealed that effect of treatment T10 [Nano DAP @ 40 ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹] was found best and recorded significantly the highest plant height (cm) i.e., 27.17 cm, 74.74 cm, 98.27 cm and 120.67 cm respectively, whereas treatment T5 [Nano urea @ 60 ppm + RD of P&K (60:60)] recorded significantly the lowest plant height (cm) i.e., 21.75 cm, 67.16 cm, 93.85 and 108.02 cm respectively

Table 1: Effect of Integrated Nutrient [Nano fertilizer (nano urea and nano DAP) and biofertilizer (azotobacter and PSB)]

Management on Plant population (plants m⁻²) and plant height (cm) of mustard

Symbols	Treatments	Plant population (plants m ⁻²)		Plant height (cm)			
		20DAS	Atharvest	30DAS	60DAS	90DAS	Atharvest
T1	RDF(120:60:60) + Sulphur @ 25 kg ha ⁻¹	11.02	10.9	25.89	73.02	97.19	117.86
T2	RDF(120:60:60) + Azotobacter @ 2 kg ha ⁻¹	11.01	10.72	24.61	71.3	96.11	115.08
T3	RDF(120:60:60) + PSB @ 4 kg ha ⁻¹	10.97	10.78	25.1	72.51	96.8	117.22
T4	RDF(120:60:60) + Azotobacter @ 2 kg ha ⁻¹ + PSB @ 4 kg ha ⁻¹	11.08	11.06	26.91	74.48	98.09	120.29
T5	Nano urea @ 60 ppm + RD of P&K (60:60)	11.11	10.3	21.75	67.16	93.85	108.02
T6	Nano DAP @ 40 ppm + RD of N&K (120:60)	11.11	10.42	22.54	68.37	94.44	110.16
T7	Nano urea @ 60 ppm + RD of P&K (60:60) + Azotobacter @ 2 kg ha ⁻¹	11.05	10.54	23.33	69.58	95.03	112.3
T8	Nano urea @ 60 ppm + RD of P&K (60:60) + Azotobacter @ 2 kg ha ⁻¹ + PSB @ 4 kg ha ⁻¹	11.06	10.6	23.82	70.09	95.42	112.94
T9	Nano DAP @ 40 ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha ⁻¹	11.05	11.02	26.68	74.23	97.88	120
T10	Nano DAP @ 40 ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha ⁻¹ + PSB @ 4 kg ha ⁻¹	11.09	11.08	27.17	74.74	98.27	120.67
F-test		NS	NS	S	S	S	S
S.E.(m) (±)		0.22	0.19	0.21	0.24	0.16	0.38
C.D. @ 5%		0.65	0.58	0.63	0.72	0.49	1.12
CV		3.43	3.14	1.49	0.59	0.3	0.57

3.3 Number of leaves plant⁻¹

According to the Table no. 2 data pertaining to number of leaves plant⁻¹ of mustard (*Brassica juncea* L.) at 30, 60, 90 and at harvest, it was revealed that the effect of treatment T₁₀ [Nano DAP @ 40 ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹] was found best and recorded significantly the highest number of leaves plant⁻¹ i.e., 15.15, 19.89, 22.12 and 19.42 respectively, whereas treatment T₅ [Nano urea @ 60 ppm + RD of P&K (60:60)] recorded significantly the lowest number of leaves plant⁻¹ i.e., 7.77, 8.11, 15.18 and 7.52 respectively.

Table 2.

Effect of Integrated Nutrient [Nano fertilizer (nano urea and nano DAP) and biofertilizer (azotobacter and PSB)] Management on number of leaves plant⁻¹ of mustard

Number of leaves plant ⁻¹					
Symbols	Treatments	30DAS	60DAS	90DAS	At harvest
T1	RDF(120:60:60) + Sulphur @ 25 kg ha ⁻¹	13.33	17.35	20.56	16.82
T2	RDF(120:60:60) + Azotobacter @ 2 kg ha ⁻¹	11.81	14.77	19	14.22
T3	RDF(120:60:60) + PSB @ 4 kg ha ⁻¹	12.07	15.31	19.43	14.77
T4	RDF(120:60:60) + Azotobacter @ 2 kg ha ⁻¹ + PSB @ 4 kg ha ⁻¹	14.95	19.58	21.91	19.04
T5	Nano urea @ 60 ppm + RD of P&K (60:60)	7.77	8.11	15.18	7.52
T6	Nano DAP @ 40 ppm + RD of N&K (120:60)	9.03	10.15	16.31	9.57
T7	Nano urea @ 60 ppm + RD of P&K (60:60) + Azotobacter @ 2 kg ha ⁻¹	10.29	12.19	17.44	11.62
T8	Nano urea @ 60 ppm + RD of P&K (60:60) + Azotobacter @ 2 kg ha ⁻¹ + PSB @ 4 kg ha ⁻¹	10.55	12.73	17.87	12.17
T9	Nano DAP @ 40 ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha ⁻¹	14.59	19.39	21.69	18.87
T10	Nano DAP @ 40 ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha ⁻¹ + PSB @ 4 kg ha ⁻¹	15.15	19.89	22.12	19.42

F-test	S	S	S	S
S.E.(m) (±)	0.21	0.35	0.21	0.34
C.D.@ 5%	0.63	1.03	0.63	1.01
CV	3.79	4.02	1.93	4.1

3.4 Number of primary branches plant⁻¹

According to the Table no. 3 data pertaining to number of primary branches plant⁻¹ of mustard (*Brassica juncea* L.) at 60, 90 and at harvest, it was revealed that effect of treatment T₁₀ [Nano DAP @ 40 ppm + RD of N & K (120:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹] was found best and recorded significantly the highest number of primary branches plant⁻¹ i.e., 5.38, 6.49 and 6.1 respectively, where- as treatment T₅ [Nano urea @ 60 ppm + RD of P & K (60:60)] recorded significantly the lowest number of primary branches plant⁻¹ i.e., 4.26, 5.64 and 5.08 respectively.

Table 3. Effect of Integrated Nutrient [Nano fertilizer (nano urea and nano DAP) and biofertilizer (azotobacter and PSB)] Management on number of primary branches plant⁻¹ of mustard

Number of primary branches plant⁻¹				
Symbols	Treatments	60DAS	90DAS	At harvest
T1	RDF(120:60:60) + Sulphur @ 25 kg ha ⁻¹	5.07	6.25	5.84
T2	RDF(120:60:60) + Azotobacter @ 2 kg ha ⁻¹	4.8	6.04	5.63
T3	RDF(120:60:60) + PSB @ 4 kg ha ⁻¹	4.86	6.08	5.64
T4	RDF(120:60:60) + Azotobacter @ 2 kg ha ⁻¹ + PSB @ 4 kg ha ⁻¹	5.34	6.46	6.08
T5	Nano urea @ 60 ppm + RD of P & K (60:60)	4.26	5.64	5.08
T6	Nano DAP @ 40 ppm + RD of N & K (120:60)	4.32	5.67	5.14
T7	Nano urea @ 60 ppm + RD of P & K (60:60) + Azotobacter @ 2 kg ha ⁻¹	4.53	5.84	5.35
T8	Nano urea @ 60 ppm + RD of P & K (60:60) +	4.59	5.87	5.41

	Azotobacter @2 kg ha ⁻¹ +PSB@4 kgha ⁻¹			
T9	Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter@2 kgha ⁻¹	5.28	6.42	6.04
T10	Nano DAP @ 40ppm + RDofN&K (120:60) + Azotobacter @2 kg ha ⁻¹ +PSB@4 kgha ⁻¹	5.38	6.49	6.1
F-test		S	S	S
S.E.(m) (±)		0.07	0.05	0.04
C.D.@ 5%		0.22	0.14	0.13
CV		2.61	1.38	1.31

3.5 Number of secondary branches plant⁻¹

According to the Table no. 4 data pertaining to number of secondary branches plant⁻¹ of mustard (*Brassica juncea* L.) at 60, 90 and at harvest, it was revealed that the effect of treatment T₁₀ [Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹] was found best and recorded significantly the number of secondary branches plant⁻¹ i.e., 10.19, 12.28 and 12.0 respectively, where- as treatment T₅ [Nano urea @ 60ppm + RD of P&K (60:60)] recorded significantly the lowest number of secondary branches plant⁻¹ i.e., 8.24, 10.82 and 10.46 respectively.

Table 4. Effect of Integrated Nutrient [Nano fertilizer (nano urea and nano DAP) and biofertilizer (azotobacter and PSB)] Management on number of secondary branches plant⁻¹ of mustard.

Number of secondary branches plant ⁻¹				
Symbols	Treatments	60DAS	90DAS	At harvest
T1	RDF(120:60:60) + Sulphur @ 25 kgha ⁻¹	9.66	11.89	11.64
T2	RDF(120:60:60) + Azotobacter @ 2 kgha ⁻¹	9.12	11.55	11.28
T3	RDF(120:60:60) + PSB @ 4 kgha ⁻¹	9.26	11.62	11.36
T4	RDF(120:60:60) + Azotobacter @ 2 kg ha ⁻¹ + PSB @ 4 kg ha ⁻¹	10.09	12.25	11.98
T5	Nano urea @ 60ppm + RD of P&K (60:60)	8.24	10.82	10.46

T6	Nano DAP @ 40ppm + RDofN&K (120:60)	8.38	10.91	10.54
T7	Nano urea @ 60ppm + RD of P&K (60:60)+ Azotobacter@2 kgha ⁻¹	8.79	11.21	10.92
T8	Nano urea @ 60ppm + RDofP&K (60:60) + Azotobacter @2 kg ha ⁻¹ +PSB@4 kgha ⁻¹	8.93	11.28	11
T9	Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter@2 kgha ⁻¹	10.05	12.21	11.92
T10	Nano DAP @ 40ppm + RDofN&K (120:60) + Azotobacter @2 kg ha ⁻¹ +PSB@4 kgha ⁻¹	10.19	12.28	12
F-test		S	S	S
S.E.(m) (±)		0.07	0.09	0.09
C.D.@ 5%		0.22	0.25	0.25
CV		1.36	1.27	1.3

3.6. Rootlength (cm): The analysis of effect of various treatments has been thoroughly examined and the results have been presented in Table 5. The rootlength (cm) per plant of mustard (*Brassica juncea* L.) depicted effect of treatment T10 [Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter @2 kg ha⁻¹ +PSB@4kgha⁻¹] was found best and recorded significantly the highest rootlength (cm) i.e., 71.28 cm. The 2nd best treatment i.e., T4 [RDF (120:60:60) + Azotobacter @2 kg ha⁻¹ + PSB@4 kg ha⁻¹] was found with 70.89 cm root length (cm) where-as treatment T5 [Nano urea @60ppm+RDofP&K(60:60)] recorded significantly the lowest rootlength (cm) i.e., 57.06cm. It was also observed that the effect of Treatment T4 [RDF (120:60:60) + Azotobacter @2 kgha⁻¹ + PSB @4 kg ha⁻¹] and T9 [Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter@2 kg ha⁻¹] was found statistically at par with treatment T10 [Nano DAP @ 40ppm + RD of N&K(120:60)+Azotobacter@2kgha⁻¹+PSB @4 kgha⁻¹].

3.7. Daysto 50%flowering: The data pertaining to was recorded to Daysto 50%flowering in presented table no. 5. The effect of treatment T10 [Nano DAP@40ppm+RDofN&K(120:60)+Azotobacter@2kgha⁻¹+PSB@4kgha⁻¹] was found best and recorded significantly the lowest Daysto 50% flowering i.e., 44.12 days. The 2nd best treatment i.e., T4 [RDF (120:60:60) + Azotobacter @2kg ha⁻¹ + PSB @4 kg ha⁻¹] was found with 44.39 days for 50% flowering where-as

treatment T5 [Nano urea @ 60ppm + RD of P&K (60:60)] recorded significantly the highest Days to 50% flowering i.e., 52.72 days. It was also observed that the effect of Treatment T4 [RDF (120:60:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹] and T9 [Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha⁻¹] was found statistically at par with treatment T10 [Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹].

3.8. Daysto 50% maturity: The data pertaining to was recorded to Daysto 50% maturity in presented table no. 5. It was found that the effect of treatment T10 [Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹] was found best and recorded significantly the lowest Daysto 50% maturity i.e., 56.56 days. The 2nd best treatment i.e., T4 [RDF (120:60:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹] was found with 57.01 days for 50% maturity where-as treatment T5 [Nano urea @ 60ppm + RD of P&K (60:60)] recorded significantly the highest Days to 50% maturity i.e., 69.98 days. It was also observed that the effect of Treatment T4 [RDF (120:60:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹] and T9 [Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha⁻¹] was found statistically at par with treatment T10 [Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹].

Table 5. Effect of Integrated Nutrient [Nanofertilizer (nanourea and nano DAP) and biofertilizer (azotobacter and PSB)] Management on root length (cm), daysto 50% flowering and daysto 50% maturity of mustard

Symbols	Treatments	Root length (cm)	Daysto 50% flowering	Daysto 50% maturity
T1	RDF(120:60:60) + Sulphur @ 25 kg ha ⁻¹	68.1	46.12	59.86
T2	RDF(120:60:60) + Azotobacter @ 2 kg ha ⁻¹	64.92	48.12	62.92
T3	RDF(120:60:60) + PSB @ 4 kg ha ⁻¹	65.76	47.42	62.14
T4	RDF(120:60:60) + Azotobacter @ 2 kg ha ⁻¹ + PSB @ 4 kg ha ⁻¹	70.89	44.39	57.01
T5	Nano urea @ 60ppm + RD of P&K (60:60)	57.06	52.72	69.98
T6	Nano DAP @ 40ppm +	59.4	51.42	68.26

	RDofN&K (120:60)			
T7	Nano urea @ 60ppm + RD of P&K (60:60)+ Azotobacter@2 kg ha^{-1}	61.74	50.12	65.98
T8	Nano urea @ 60ppm + RDofP&K (60:60) + Azotobacter @2 kg ha^{-1} +PSB@4 kg ha^{-1}	62.58	49.42	65.2
T9	Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter@2 kg ha^{-1}	70.44	44.82	57.58
T10	Nano DAP @ 40ppm + RDofN&K (120:60) + Azotobacter @2 kg ha^{-1} +PSB@4 kg ha^{-1}	71.28	44.12	56.56
	F-test	S	S	S
	S.E.(m) (\pm)	0.44	0.31	0.42
	C.D.@ 5%	1.3	0.92	1.25
	CV	1.16	1.12	1.16

3.7 Number of siliqua plant⁻¹

According to the Table no. 6 data pertaining to the number of siliqua plant⁻¹ of mustard (*Brassica juncea* L.) depicts that the effect of treatment T10 [Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter @2kg ha^{-1} + PSB @4 kg ha^{-1}] was found best and recorded significantly the highest number of siliqua per plant i.e., 117.17. The 2nd best treatment i.e., T4 [RDF (120:60:60) + Azotobacter@2 kg ha^{-1} + PSB @4 kg ha^{-1}] was found with 116.84 number of siliqua per plant where-as treatment T5 [Nano urea@60ppm+RDofP&K(60:60)] recorded significantly the minimum number of siliqua per plant i.e., 96.63. It was also observed that the effect of Treatment T4 [RDF(120:60:60)+Azotobacter@2kg ha^{-1} +PSB@4kg ha^{-1}] and T9 [Nano DAP@40ppm +RDofN&K(120:60)+Azotobacter@2kg ha^{-1}] was found statistically at par with treatment T10 [Nano DAP@40ppm+RDofN&K(120:60)+Azotobacter@2kg ha^{-1} +PSB@4kg ha^{-1}].

3.8 Length of siliqua (cm)

According to the table no. 6 data pertaining to length of siliqua of mustard. it was found that the effect of treatment T₁₀ [Nano DAP @ 40ppm + RD of N&K (120:60) + *Azotobacter* @2 kg ha⁻¹ + PSB @4 kg ha⁻¹] was found best and recorded significantly the highest length of siliqua (cm) i.e., 6.80 cm. The 2nd best treatment i.e., T₄ [RDF (120:60:60) + *Azotobacter* @2 kg ha⁻¹ + PSB @4 kg ha⁻¹] was found with 6.71 cm length of siliqua (cm) where-as treatment T₅ [Nano urea @ 60ppm + RD of P&K (60:60)] recorded significantly the lowest length of siliqua (cm) i.e., 4.38 cm. It was also observed that the effect of Treatment T₄ [RDF (120:60:60) + *Azotobacter* @2 kg ha⁻¹ + PSB @4 kg ha⁻¹] and T₉ [Nano DAP @ 40ppm + RD of N&K (120:60) + *Azotobacter* @2 kg ha⁻¹] was found statistically at par with treatment T₁₀ [Nano DAP @ 40ppm + RD of N&K (120:60) + *Azotobacter* @2 kg ha⁻¹ + PSB @4 kg ha⁻¹].

3.9. Number of seeds siliqua⁻¹

According to the table no. 6 data pertaining to number of seeds siliqua⁻¹ of mustard. it was found that the effect of treatment T₁₀ [Nano DAP @ 40ppm + RD of N&K (120:60) + *Azotobacter* @2 kg ha⁻¹ + PSB @4 kg ha⁻¹] was found best and recorded significantly the highest number of seeds per siliqua i.e., 20.2. The 2nd best treatment i.e., T₄ [RDF (120:60:60) + *Azotobacter* @2 kg ha⁻¹ + PSB @4 kg ha⁻¹] was found with 19.81 number of seeds per siliqua where-as treatment T₅ [Nano urea @ 60ppm + RD of P&K (60:60)] recorded significantly the lowest number of seeds per siliqua i.e., 12.95 days. It was also observed that the effect of Treatment T₄ [RDF (120:60:60) + *Azotobacter* @2 kg ha⁻¹ + PSB @4 kg ha⁻¹] and T₉ [Nano DAP @ 40ppm + RD of N&K (120:60) + *Azotobacter* @2 kg ha⁻¹] was found statistically at par with treatment T₁₀ [Nano DAP @ 40ppm + RD of N&K (120:60) + *Azotobacter* @2 kg ha⁻¹ + PSB @4 kg ha⁻¹].

3.10. Weight of seed plant⁻¹(g)

According to the table no. 6 data pertaining to weight of seed siliqua⁻¹ (g) of mustard (*Brassica juncea* L.) depicts that the effect of treatment T₁₀ [Nano DAP @ 40ppm + RD of N&K (120:60) + *Azotobacter* @2 kg ha⁻¹ + PSB @4 kg ha⁻¹] was found best and recorded significantly the highest weight of seed per siliqua (g) i.e., 16.37g. The 2nd best treatment i.e., T₄ [RDF (120:60:60) + *Azotobacter* @2 kg ha⁻¹ + PSB @4 kg ha⁻¹] was found with 15.63g weight of seed per siliqua (g) where-as treatment T₅ [Nano urea @ 60ppm + RD of P&K (60:60)] recorded significantly the minimum weight of seed per siliqua (g) i.e., 5.38. It was also observed that the effect of Treatment T₄ [RDF (120:60:60) + *Azotobacter* @2 kg ha⁻¹ + PSB @4 kg ha⁻¹] and T₉ [Nano DAP @ 40ppm + RD of N&K (120:60) + *Azotobacter* @2 kg ha⁻¹] was found statistically at par with treatment

T₁₀[NanoDAP@40ppm+RDofN&K(120:60)+Azotobacter@2kg ha^{-1} +PSB@4kg ha^{-1}].

3.11. 1000seed weight (g)

According to the table no. 6 data pertaining to the 1000 seed weight (g) of mustard (*Brassica juncea* L.) depicts that the effect of treatment T₁₀ [Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter @ 2kg ha^{-1} + PSB @4 kg ha^{-1}] was found best and recorded significantly the highest 1000 seed weight (g) i.e., 6.92 g. The 2nd best treatment i.e., T₄ [RDF (120:60:60) + Azotobacter @2 kg ha^{-1} + PSB @4 kg ha^{-1}] was found with 6.75 g 1000 seed weight (g) where-as treatment T₅ [Nano urea @ 60ppm + RD of P&K (60:60)] recorded significantly the minimum 1000 seed weight (g) i.e., 4.29 g. It was also observed that the effect of Treatment T₄ [RDF (120:60:60) + Azotobacter @2 kg ha^{-1} + PSB @4 kg ha^{-1}] and T₉ [Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter @2 kg ha^{-1}] was found statistically at par with treatment T₁₀ [Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter @2 kg ha^{-1} + PSB @4 kg ha^{-1}].

Table 6. Effect of Integrated Nutrient [Nano fertilizer (nano urea and nano DAP) and biofertilizer (azotobacter and PSB)] Management on Number of siliqua plant⁻¹, Length of siliqua (cm), Number of seeds siliqua⁻¹, Weight of seed plant⁻¹ (g) and 1000 seed weight (g) of mustard.

Symbols	Treatments	Number of siliqua plant⁻¹	Length of siliqua (cm)	Number of seeds siliqua⁻¹	Weight of seed plant⁻¹ (g)	1000 seed weight (g)
T1	RDF(120:60:60) + Sulphur @25 kg ha ⁻¹	111.73	6.25	18.78	13.25	6.31
T2	RDF(120:60:60) + Azotobacter @2 kg ha ⁻¹	106.29	5.70	17.06	10.34	5.70
T3	RDF(120:60:60) + PSB @4 kg ha ⁻¹	107.51	5.90	17.62	11.24	5.93
T4	RDF(120:60:60) + Azotobacter @2 kg ha ⁻¹ + PSB @4 kg ha ⁻¹	116.84	6.71	19.81	15.63	6.75
T5	Nano urea @ 60 ppm + RD of P&K (60:60)	96.63	4.38	12.95	5.38	4.29
T6	Nano DAP @ 40 ppm + RD of N&K (120:60)	100.85	4.77	14.21	6.76	4.71
T7	Nano urea @ 60 ppm + RD of P&K (60:60) + Azotobacter @2 kg ha ⁻¹	105.07	5.12	15.37	8.23	5.09
T8	Nano urea @ 60 ppm + RD of P&K (60:60) + Azotobacter @2 kg ha ⁻¹ + PSB @4 kg ha ⁻¹	102.07	5.32	15.93	8.66	5.32
T9	Nano DAP @ 40 ppm + RD of N&K (120:60) +	115.95	6.60	19.94	15.48	6.69

	Azotobacter@2 kgha ⁻¹					
T10	Nano DAP @ 40ppm + RDofN&K (120:60) + Azotobacter @2 kg ha ⁻¹ +PSB@4 kgha ⁻¹	117.17	6.80	20.2	16.37	6.92
	F-test	S	S	S	S	S
	S.E.(m) (±)	0.74	0.53	0.25	0.38	0.09
	C.D.@ 5%	2.19	0.74	0.74	1.13	0.27
	CV	1.18	2.52	2.52	5.93	2.74

Conclusion

Treatment T10 [Nano DAP @ 40ppm + RD of N&K (120:60) + Azotobacter @ 2 kg ha⁻¹ + PSB @ 4 kg ha⁻¹] was found to be best in terms of growth and yield attributes. It was found to have best effect in terms of yield attributes.

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