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Ajay Kumar Shah
Ph.D. Scholar, Department of Forestry, JNKVV, Jabalpur, Madhya Pradesh, India

Anil Kumar Kori
Ph.D. Scholar, Department of Forestry, JNKVV, Jabalpur, Madhya Pradesh, India

Kamal Kishor Patel
Ph.D. Scholar, Department of soil science and agricultural chemistry, JNKVV, Jabalpur, Madhya Pradesh, India.

Dr. R Bajpai
Professor, Department of Forestry, College of Agriculture, JNKVV, Jabalpur, Madhya Pradesh, India

Corresponding Author:
Ajay Kumar Shah
Ph.D. Scholar, Department of Forestry, JNKVV, Jabalpur, Madhya Pradesh, India

Effect of fertilizer levels on performance of mustard crop under agroforestry systems

Ajay Kumar Shah, Anil Kumar Kori, Kamal Kishor Patel and Dr. R Bajpai

Abstract
The experiment was conducted in the new dusty acre area at the research farm of forestry, Jawaharlal Nehru Krishi Vishwavidyalaya, Madhya Pradesh India. This experiment was run on agricultural crop (Indian mustard) with two tree system (*Gmelina* and *Dalbergia*) under fertilizer treatments, the statistical tool for analysis and data interpretation by FRBD (Factorial randomized block design). The first factor were two agroforestry system *i.e. Gmelina arborea* + Mustard and *Dalbergia sissoo* + Mustard and second were three Fertilizer treatments *i.e.* 75%, 100% and 125% recommended dose of fertilizer (RDF) with four replication. The present studied revealed that; field emergence at 14 day after sowing (DAS), Plant height (cm) at harvest, Branches plant^{-1} (numbers), 1000 grain weight, Biological yield (q ha^{-1}), Seed yield (q ha^{-1}) and Harvest index (%) were *Gmelina* significant over to *Dalbergia* factor. moreover second factor was fertility level 125% (F_3) found significant to other fertility levels (F_2 and F_1) of parameter of mustard *i.e.* plant population, plant height, silique branches^{-1}, silique Length, number of seed silique^{-1}, 1000 grain weight, seed yield and harvest index. The PAR during 30 DAS of mustard the APAR and IPAR were found non- significant, 60 and 90 DAS of mustard the APAR and IPAR were found significant and Non–significant respectively.

Keywords: Agroforestry, fertilizer levels, PAR, productivity etc

Introduction
Rapeseed and mustard are among the most important oilseeds in India and belong to the cruciferous genus of the *Crucifera* family. There are four oilseed species in Brassica: *B. compostris* (B. canola), *B. juncia* (Indian mustard), *B. napus* (winter and spring oilseed rape) and *B. carinata.* Mustard oil demand is forecast to show an average annual increase of 4.3% in the same year from 2023 to 2028 (IMARC, 2023) [12], but mustard oil production accounts for almost 40% of the total cooking oil production in the country. Mustard is produced throughout North India, with a main growing area in Rajasthan (29 lakh tons), Haryana, MP and Gujarat (total 20 lakh tons), UP (8.8 lakh tons) and Punjab (FICCI 2023) [7]. This gap between demand and production is complemented by quantitative and qualitative improvements. This is achieved with a sustainable tool such as an agroforestry system with the right fertilizer according to the Recommended dose Fertilizer (RDF). Broadly speaking, agroforestry is a sustainable land management system that increases overall production, combines agricultural crops, pole crops, and forest plants and/or animals simultaneously or sequentially, and uses management practices consistent with local cultural population patterns (Bene *et al.* 1977) [3]. The use of fertilizers (NPK) is more efficient in mustard production (Aulakh *et al*., 1980 and Rathore *et al.*, 2022) [2, 3]. The photosynthesis active radiation (PAR) results in greater variation in the frequency of daily PAR levels, with shadier locations more often having low PAR levels. These PAR values vary in different agroforestry systems.

Materials and Methods
Study site
The field experiment was conducted in the New Dusty Acre area at the Research Farm of Forestry, Jawaharlal Nehru Krishi Vishwavidyalaya, Madhya Pradesh.

Experimental details
There are 3 recommended fertilizer rates (RDF) for F_1 -75% NPK @ 50:30:30 kg ha-^{1}, F_2 -100% NPK @ 60:40:40 kg ha-^{1} and F_3 -125% NPK @ 75:50:50 kg ha^{-1} for mustard (*Brassica juncea*) Pusa Tarak with 30 cm row spacing with 4 repetitions under agroforestry trees with a factor of 2, i.e. *Gmelina arbore* and *Dalbergia sissoo*. The distance between the rows and the trees at distances of 2.5 m and 8 m at *Gmelina* and 5 m and 5 m at *Dalbergia*.

Data recording and analysis

Recorded observation of mustard growth in different paramet ers *i.e.* Plant population (m^2), Plant height (cm) at harvest, Branches plant^{-1} (numbers), Silique branches^{-1}, Length of silique (cm), Number of seeds silique^{-1}, 1000 grain weight, Biological yield (q ha^{-1}), Seed yield (q ha^{-1}) and Straw yield (q ha^{-1}), Harvest index (%).

Statistical analysis of data

Data were subjected to standard analysis of variance using factorial randomized block design (FRBD) technique. Statistical analysis was performed on one-year data for various parameters. The mean treatment effect was compared at a significance level of $p< 0.05$ (Gomez and Gomez 1984) [10].

Results and Discussion

The result shown as original research work that were explaining by different parameters those are reflected in one by one *i.e.*

Field emergence at 14 DAS

Data in relation to field emergence at 14 DAS of mustard recorded under agroforestry systems were presented in Table 1 revealed that showed significant variations under systems but fertility levels showed non- significant. On an average, field emergence of mustard at 14 DAS under *Gmelina arborea* was higher than *Dalbergia sissoo*. As regards to the systems, significantly higher field emergence (88.08 MRL^{-1}) of mustard was recorded in *Gmelina arborea* as compared to *Dalbergia sissoo* (81.67 MRL^{-1}) during the research period. The fertilizer levels were non -significant effect on field emergence in mustard crops. The highest field emergence was noted as F_3 (109.5 MRL^{-1}) followed by F_2 (84.00 MRL^{-1}) and F_1 (61.13 MRL^{-1}) fertilizer levels. the germination rates observed in these field experiments it was reported by Chen *et al.* (2012) [6], Wilkins *et al*. (2001) [37] another result on improvement of seed germination and seedling establishment for many field crops reported by Khajeh-Hosseini *et al.,* (2003) [14], Sadeghian and Yavari (2004) [26] and Singh *et al*. (2018) [31].

Plant Population (m^2)

The average plant height of mustard at 30 DAS under *Gmelina* was higher than that under *Dalbergia*. As regards to the difference between systems, a higher plant population of mustard was recorded in *Gmelina* (110.1 m^2) compared to *Dalbergia* (107.2 m^2) during the year. The fertilizer levels had a significant effect on the plant population of mustard during the year. The significantly highest populations of 129.5 m^2 was noted as F_3 fertilizer levels as compare to F_2 (105.3 m^2) and F_1 (91.1 m^2) fertilizer levels. These studies shown on interaction between density and fertilizer reported by Nelder 1963 [18], Buttery 1969 [4] and Tajul *et al.,* (2013) [34].

Plant height (cm) of mustard crop at Harvest

On an average, plant height at harvest, mustard in *Gmelina arborea* was higher than in *Dalbergia sissoo* presented in Table No.1, As regards to the systems, significantly higher plant heights (134.5 cm) of mustard were recorded in *Gmelina arborea* as compared to *Dalbergia sissoo* (104.5 cm) during the year, The fertilizer levels had significant effects on mustard plant height with the significantly highest heights of F_3 (133.4 cm) followed by F_2 (113.9 cm) and F_1 (111.3 cm). Shoot height, leaf area and shoot fresh weight increased with the increasing of nitrogenous fertilizer or other fertilizer reported through Kumar & Kumar (2008) [15], Rashid *et al.,* (2010) [23], Ghodrat *et al.* (2012) [8] and Shagata *et al.,* (2020) [27].

Branches plant^{-1} (numbers)

The number of branches plant^{-1} in mustard were regards to the systems, significantly higher branches of mustard plant^{-1} of mustard was recorded in *Dalbergia sissoo* (4.4) as compared to *Gmelina arborea* (3.0). The fertilizer levels had effects on branches plant^{-1} of mustard during non-significant found but higher in number noted on F_3 followed by F_2 and F_1 presented in Table No.1 the branches plant $^{-1}$ influences by spacing and age of *Dalbergia* trees as compare to *Gmelina* trees this impact caused lodging effect on mustard crop in this reasons number of branches par plant of mustard crop was higher found under *Dalbergia* This phenomenal effect reported by Wu *et al.,* (2016) [38] and Wu *et al.,* (2022) [39].

Silique branches^{-1}

Silique branches^{-1} of mustard in *Gmelina arborea* were higher than in *Dalbergia sissoo* in year. As regards to the systems, higher silique branches^{-1} of mustard was recorded in *Gmelina arborea* (22.7) as compared to *Dalbergia sissoo* (18.9) during the year, Silique branches^{-1} F_3 (24.6) was significantly superior noted in fertilizer levels after that F_2 (20.1) and F_1 (17.7) furthermore F_2 was at par with F_1 during the year. The interaction of agroforestry systems F_3 levels of fertility proved superior to F_1 in both systems. While F_3 levels of fertility in *Gmelina* gave significantly higher silique of 28.0 it was comparatively higher to the same fertility levels in *Gmelina* though the difference between F_3 and F_2 was significant under the *Gmelina* system, whereas at par found in *Dalbergia system* the data reflected in Table No. 1. The height gain after these treatments can be attributed to the combined of inorganic fertilizer, ultimately providing the plant with a better environment for good growth and development that kinds of research reported by Sharma *et al.,* (2017) [28], Singh *et al.,* (2018) [31] and Chavan *et al.,* (2021) [5].

Length of silique (cm)

As regards to the systems, non-significant silique Length (4.64 cm) of mustard were recorded in *Gmelina arborea* as compared to *Dalbergia sissoo* (4.55 cm) in the year, Furthermore under fertilizer levels silique Length 4.94 was noted as F_3 fertilizer levels significantly superior to F_2 (4.55) and F_1 (4.29) during the year, but F_2 was significant to F_1. The interaction under agroforestry system fertility levels F_3 and F_2 was significant to F_1 under *Gmelina* and *Dalbergia* System whereas F_3 was at par with F_2 under *Gmelina* System and significant in *Dalbergia* System the data presented in Table No.2 Yogesh *et al.,* (2009) [40], Ahmed *et al.,* (2019) [1], Shorna *et al.,* (2020) [29], Rana *et al.,* (2020) [22] and Chavan *et al.,* (2021) [5].

Number of Seeds silique^{-1}

The Table 2 presents data As regards to the systems, the number of seed silique^{-1} non-significant effect on mustard were recorded in *Dalbergia* (12.75) as compared to *Gmelina* (13.71) during year. As regards to the fertilizer levels had a significant effect on the number of mustard seeds silique^{-1} was significantly higher in F_3 (14.74) fertilizer level among other treatments F_2 (12.78) and F_1 (12.18). Whereas F_2 fertilizer level was at par with F_1 fertilizer level. Furthermore interaction between Agroforestry system under *Gmelina* and *Dalbergia* system the F_3 (14.20, 15.30) was significantly superior to F_2 (12.28, 13.28) and F_1 (11.74, 12.58) treatments respectively whereas F_2 fertilizer level was at par with F_1 fertilizer level. Mustard yield per plant is severely restricted by the seed number per silique Wang *et al.*, (2021) [36], Chavan *et al.*, (2021) [5] and Kaur *et al.*, (2023) [13].

1000 grain weight of mustard

The table 2 showed that as regard to the system, *Gmelina* (3.59) was significantly superior to *Dalbergia* (3.04) system based 1000 grain weight of mustard, moreover regard to Fertilizer levels the F_3 (4.17) treatments was significantly superior to F_2 (2.94) and F_1 (2.83), when that F_2 was at par with F_1. The interaction effect were shown that *Gmelina* and *Dalbergia* both constant in condition, the 1000 grain weight of F_3 (4.38 and 3.97) was found significantly superior to F_2 (3.19 and 2.47) and F_1 (3.18 and 2.69) when that F_2 was at par with F_1 respectively reported through Kaur *et al.*, (2023) [13].

Biological yield (q ha^{-1})

The table 3 reflected that result of biological yield (q ha^{-1}) *i.e.* as regard to system, *Gmelina* (19.30) was at par with *Dalbergia* (18.52), moreover regard to Fertility levels the F_3 (21.37) was significant superior to F_2 (18.70) and F_1 (16.66), whereas F_2 was at par with F_1. The interaction was found non-significant this finding reflected in Pal *et al.*, (2008) [19], Kaur *et al.*, (2023) [13].

Seed yield (q ha^{-1})

The table 3 presented that result of seed yield (q ha^{-1}) was significantly under systems as well as fertility levels *i.e.* as regard to system *Gmelina* (3.56) was significant to *Dalbergia* (2.75), moreover regard to Fertility levels the F_3 (3.49) and F_2 (3.44) were significant superior to F_1 (2.53), whereas F_3 was at par with F_2, however the interaction effect on seed yield of mustard crop non- significant in systems as well as fertility levels. These studies on seed yield was effected by organic, inorganic and nutrient substances reported by Giri and Schillinger (2003) [9], Yogesh *et al*., (2009) [40] Ibrahim *et al.*, (2020) [11], Shorna *et al*., (2020) [29] Sreenivasasareddy *et al*., (2021) [33] and Kaur *et al.*, (2023) [13] and seed yield effect by PAR (Photosynthetic Active Radiation), more PAR have more productivity of crops the *Gmelina* factor have more productive as compare to *Dalbergia* under systems some researcher reported by Wünsche *et al*. 2000 [21], Rosati *et al*. 2021 [25].

Straw yield (q ha^{-1})

The table 3 shown that result of straw yield (q ha^{-1}) was non-significant under systems but significant in fertility levels, the F_3 (17.88) was significant to F_1 (14.13) and at par with F_2 (15.26) when that F_2 was at par with F_1 whereas interaction between system and fertility levels were non-significant that is reported by Singh *et al.* (2014) [32] and Kaur *et al.*, (2023) [13].

Harvest index (%)

The table 3 presented that result of harvest index (%) was significantly under systems as well as fertility levels *i.e.* as regard to system *Gmelina* (18.68) was significant to *Dalbergia* (15.03), moreover regard to Fertility levels the F_3 (18.70) was significant superior to F_2 (18.55) and F_1 (16.66), whereas F_2 was at par with F_1, however the interaction effect on seed yield of mustard crop non- significant in systems as well as fertility levels similar result show by Parvaiz *et al.*, (1983) [20] and Tripathi *et al.*, (2010) [35].

Photosynthetically active radiation (PAR) under *Gmelina* and *Dalbergia* at 30, 60 and 90 DAS

A fundamental term in the quantification of light used by plants in the photosynthesis process is the fraction of absorbed photosynthetically active radiation (APAR), calculated as the ratio of absorbed to total incident PAR (IPAR) in a vegetation canopy. This variable is widely used in vegetation functioning models at a range of spatial scales from the plant to the globe as an indicator of the amount of energy available for photosynthesis (McCree 1972) [16]. Data on photosynthesis active radiation on APAR and IPAR on mustard recorded under different systems and fertility levels were presented in Table 4 and 5.

Table 1: Observations obtained at Pre harvest parameter of the mustard crops

Parameters/Treatment	Field emergence (MRL^{-1}) at 14 DAS			Plant Population (m^2) at 30 DAS			Plant height (cm) of mustard crop at Harvest			Branches plant^{-1} (numbers)		
	Gmelina	*Dalbergia*	Mean	*Gmelina*	*Dalbergia*	Mean	*Gmelina*	*Dalbergia*	Mean	*Gmelina*	*Dalbergia*	Mean
F_1 (75%RDF)	60.00	62.25	61.13	88.3	94.0	91.1	124.1	98.5	111.3	2.8	3.9	3.3
F_2 (100%RDF)	81.00	87.00	84.00	109.5	101.0	105.3	128.5	99.3	113.9	3.0	4.5	3.7
F_3 (125%RDF)	123.25	95.75	109.50	132.5	126.5	129.5	151.1	115.7	133.4	3.3	4.8	4.0
Mean	88.08	81.67		110.1	107.2		134.5	104.5		3.0	4.4	
Factors	Systems (A)	Fertilizer (B)	AXB	Systems (A)	fertilizer (B)	A X B	Systems (A)	Fertilizer (B)	A X B	Systems (A)	Fertilizer (B)	A X B
S.Em±	10.13	12.41	17.54	7.0	8.6	12.1	4.8	5.9	8.3	0.3	0.4	0.5
CD (5%)	NS	37.39	52.88	21.1	25.8	36.5	14.4	17.6	24.9	0.9	1.1	1.6

Table 2: Observations obtained at Post harvest parameter of the mustard crops

Parameters/Treatment	Silique branches^{-1}			Length of silique (cm)			Number of Seeds silique^{-1}			1000 grain weight		
	Gmelina	***Dalbergia***	**Mean**	***Gmelina***	***Dalbergia***	**Mean**	***Gmelina***	***Dalbergia***	**Mean**	***Gmelina***	***Dalbergia***	**Mean**
F_1 (75%RDF)	18.8	16.7	17.7	4.33	4.26	4.29	11.78	12.58	12.18	3.19	2.47	2.83
F_2 (100%RDF)	21.5	18.8	20.1	4.69	4.42	4.55	12.28	13.28	12.78	3.18	2.69	2.94
F_3 (125%RDF)	28.0	21.3	24.6	4.91	4.97	4.94	14.20	15.28	14.74	4.38	3.97	4.17
Mean	22.7	18.9		4.64	4.55		12.75	13.71		3.59	3.04	
Factors	Systems (A)	Fertilizer (B)	A X B	Systems (A)	Fertilizer (B)	A X B	Systems (A)	fertilizer (B)	A X B	Systems (A)	Fertilizer (B)	A X B
S.Em±	1.2	1.4	2.0	0.05	0.06	0.08	0.33	0.41	0.58	0.12	0.14	0.20
CD (5%)	3.5	4.3	6.1	0.15	0.18	0.25	1.01	1.23	1.74	0.35	0.43	0.61

Table 3: Yield attributing parameter of the mustard crops

Parameters/Treatment	Biological yield (q ha^{-1})			Seed yield (q ha^{-1})			Straw yield (q ha^{-1})			Harvest index (%)		
	Gmelina	*Dalbergia*	Mean	*Gmelina*	*Dalbergia*	Mean	*Gmelina*	*Dalbergia*	Mean	*Gmelina*	*Dalbergia*	Mean
F_1 (75%RDF)	17.91	15.41	16.66	2.81	2.25	2.53	15.10	13.16	14.13	15.79	14.93	15.36
F_2 (100%RDF)	18.41	18.99	18.70	3.88	3.01	3.44	14.53	15.99	15.26	21.30	15.81	18.55
F_3 (125%RDF)	21.57	21.16	21.37	3.99	2.98	3.49	17.58	18.17	17.88	18.93	14.34	16.63
Mean	19.30	18.52		3.56	2.75		15.74	15.77		18.68	15.03	
Factors	Systems (A)	Fertilizer (B)	A X B	Systems (A)	Fertilizer (B)	A X B	systems(A)	fertilizer (B)	A X B	Systems (A)	fertilizer (B)	A X B
S.Em±	0.82	1.00	1.42	0.18	0.22	0.30	0.87	1.06	1.50	1.15	1.40	1.99
CD (5%)	2.47	3.03	4.28	0.53	0.65	0.92	2.61	3.20	4.52	3.46	4.23	5.98

Table 4: PAR (Photosynthetically active radiation) under *Gmelina* and *Dalbergia* at 30 and 60 DAS

Factor / Treatments	30 DAS						60 DAS					
	APAR			IPAR			APAR			IPAR		
	Gmelina	*Dalbergia*	Mean	*Gmelina*	*Dalbergia*	Mean	*Gmelina*	*Dalbergia*	Mean	*Gmelina*	*Dalbergia*	Mean
F_1 (75%RDF)	747.8	737.8	742.8	790.8	790.0	790.4	1167.5	536.8	852.1	1254.3	578.0	916.1
F_2 (100%RDF)	730.8	655.0	692.9	785.5	703.0	744.3	1223.8	526.8	875.3	1285.8	575.8	930.8
F_3 (125%RDF)	700.3	696.5	698.4	740.3	773.0	756.6	1152.0	505.5	828.8	1229.3	552.0	890.6
Mean	726.3	696.4		772.2	755.3		1181.1	523.0		1256.4	568.6	
	System (A)	Fertilizer (B)	A X B	System (A)	Fertilizer (B)	A X B	System (A)	Fertilizer (B)	A X B	System (A)	Fertilizer (B)	A X B
S.Em±	27.6	33.7	47.7	25.7	31.5	44.6	55.9	68.5	96.9	56.7	69.5	98.3
CD (5%)	83.1	101.7	143.9	77.5	95.0	134.3	168.6	206.5	292.0	171.0	209.4	296.2

Table 5: PAR (Photosynthetically active radiation) under *Gmelina* and *Dalbergia* at 90 DAS

Factor / Treatments	90 DAS					
	APAR			IPAR		
	Gmelina	*Dalbergia*	Mean	*Gmelina*	*Dalbergia*	Mean
F_1 (75%RDF)	684.3	337.0	510.7	755.0	388.3	571.7
F_2 (100%RDF)	719.0	377.7	548.3	892.0	416.7	654.3
F_3 (125%RDF)	619.3	434.5	526.9	790.3	479.2	634.8
Mean	674.2	383.1		812.4	428.1	
	System (A)	Fertilizer (B)	A X B	System (A)	Fertilizer (B)	A X B
S.Em±	43.7	53.5	75.7	42.8	52.5	74.2
CD (5%)	131.7	161.3	228.1	129.1	158.2	223.7

At 30, 60 and 90 DAS

The Table No.4. is presented that the systems and fertility levels at 30 DAS of mustard the APAR and IPAR were found non- significant, when that the highest APAR and IPAR on systems were recorded in *Gmelina* (726.3 and 772.2 mol m^{-2} d^{-1}) and lowest APAR and IPAR were recorded in *Dalbergia* (696.4 and 755.3 mol m^{-2} d^{-1}) respectively. Whereas the highest APAR and IPAR on fertility levels were recorded in F_1 (742.8 and 790.4 mol m^{-2} d^{-1}) and list in F_2 (692.9 and 744.3 mol m^{-2} d^{-1}) respectively. moreover systems and fertility levels, at 60 DAS of mustard the APAR and IPAR were found significant and Non–significant respectively, when that APAR and IPAR on system significantly superior were recorded in *Gmelina* (1181.1 and 1256.4 mol m^{-2} d^{-1}) to *Dalbergia* (523.0 and 568.6 mol m^{-2} d^{-1}) respectively. Whereas, the highest APAR and IPAR on fertility levels were recorded in F_2 (875.3 and 930.8 mol m^{-2} d^{-1}) respectively. Besides systems and fertility levels at 90 DAS of mustard the APAR and IPAR were found significant and Non–significant respectively, when that APAR and IPAR on system significantly superior were recorded in *Gmelina* (674.2 and 812.4 mol m^{-2} d^{-1}) to *Dalbergia* (383.1 and 428.1 mol m^{-2} d^{-1}) respectively. Whereas, the highest APAR and IPAR on fertility levels were recorded in F_2 (548.3 and 654.3 mol m^{-2} d^{-1}) respectively that is presented in Table No.5.

Conclusion

Our present investigation reflect the performance of 3 fertility levels and the mustard parameter higher performers under fertility F_3 (125% @ 60:50:50 NPK) for field emergence, Plant Population, plant height at harvest, branches $plant^{-1}$, Silique $branches^{-1}$, Length of silique, number of seed $silique^{-1}$, 1000 grain weight of mustard, Straw yield, Harvest index. *Gmelina* (726.3 and 772.2 mol m^{-2} d^{-1}) and lowest APAR and IPAR were recorded in *Dalbergia* (696.4 and 755.3 mol m^{-2} d^{-1}) respectively. Whereas the highest APAR and IPAR on fertility levels were recorded in F_1 (742.8 and 790.4 mol m^{-2} d^{-1}) and list in F_2 (692.9 and 744.3 mol m^{-2} d^{-1}) respectively and 90 DAS APAR and IPAR on system significantly superior were recorded in *Gmelina* (674.2 and 812.4 mol m^{-2} d^{-1}) to *Dalbergia* (383.1 and 428.1 mol m^{-2} d^{-1}) respectively. The recommended doses of different fertility levels the best fertility levels is F_3.

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Declarations

Ethics approval: The plant materials (Mustard variety-Pusa Tarak) used for our research work was provided by the Department of Forestry JNKVV, Jabalpur and All local, national, or international guidelines and legislation were followed on this study for the production of mustard crop.

Consent to participate

It is not applicable for our research paper.

Availability of data and materials

The data can be made available for other researchers after requested from Corresponding author.

Competing interests

There are no conflict for our research work on the site/institutions or agency.

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Authors' contributions

The correspondent author (Ajay Kumar Shah) was done the trial under Ph.D. research work in JNKVV, Jabalpur. The last author (Anil Kumar Kori) was helping in the research work and analysis of row data. The third author (R. Bajpai) was guided for this research work.

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