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Physiological evaluation of growth and yield variation of mustard (*Brassica juncea*) varieties under organic products in North-Western Indo-Gangetic Plains

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ABSTRACT

A field experiment was conducted for two years to analyze the physiological basis of variation in the growth and yield of popular mustard varieties under organic production. Twelve mustard varieties of varied duration and agroclimatic suitability were evaluated in a randomized complete block design. Results revealed that varieties NRCHB-506, RH-406, and RGN-229, being at par, registered significantly maximum leaf area index, photosynthesis rate, and chlorophyll content at all the crop growth stages, i.e., 30, 60 and 90 DAS. During both the intervals, i.e., 30-40 and 80-90 DAS, variety RH-406 followed by RGN-229 registered maximum crop growth rate, whereas,in NRCHB-101, the lowest crop growth rate was observed. At each crop growth stage, photosynthesis rate has a significant positive correlation with leaf area index, chlorophyll content, crop growth rate during 30-40 and 80-90 DAS. Varieties Pusa Mustard-25 (5.8) and Pusa Mustard-26 (5.7) recorded significantly higher primary branches plant^{-1}. However, varieties Pusa Tarak, RH-406, and RGN-229 recorded the significantly highest number of secondary branches plant^{-1}. Being at par, varieties NRCHB-506, RH-406, RGN-229, and Pusa Bold recorded a significantly higher number of silique plant^{-1}, seed yield,and stover yield than other varieties. The seed yield was found significantly and positively correlated with the crop growth rate at 80-90 DAS (r=0.600**), chlorophyll content at 90 DAS (r=0.558**), and silique plant^{-1}(r=0.518**).Therefore, it is inferred that varieties like RH-406, RGN-229, and NRCHB-506 are suitable to grow under organic nutrient management in the prevailing agro-climatic conditions.

Keywords: Correlation, crop growth rate, organic management, physiological parameters, seed yield

INTRODUCTION

Mustard (*Brassica juncea* L.) is one of the most important oilseeds worldwide. India is one of the largest producers, consumers, and importers of oilseeds globally, contributing 28.3 percent and 19.8 percent in world acreage and production of mustard, respectively (Shekhawat *et al.,* 2012).In India,rapeseed-mustard is the third most important oilseed crop after groundnut and soybean (GOI, 2017).The mustard growing areas in India are experiencing vast diversity in the agro-climatic conditions, and different species of rapeseed-mustard are grown in some or other parts of the country. Optimum agronomic traits of mustard are mostly resistance against high temperature, drought, pest, and disease, making this crop compatible with different climate and geographical conditions (Wysocki and Corp, 2002). Indian mustard requires a relatively larger amount of nutrients for the realization of higher yield potential. Hence, soil nutrition management is considered one of the most critical factors for enhancing productivity. The adverse impacts of excessive use of chemical fertilizers and toxic chemical pesticides in conventional agriculture adversely affected soil fertility and the quality of crop produce. Recently, with increased awareness of environmental and human health, organic farming is considered a better option for producing healthy food and sustaining soil health (Das *et al.,* 2010).

Since nitrogen fertilizers are costly, poor nitrogen use efficiency is of great concern. Therefore, efforts are needed to improve the contribution of applied nitrogen to grain production through organic nutrient management. This approach will reduce the environmental and production costs in agriculture. Therefore, the current trend is to explore replacing chemical fertilizers with organic ones that are eco-friendly and cost-effective.Besides this, even withsufficient irrigation water and fertilizer nutrients, higher yields are realized by selecting suitable cultivars under a particular agro-climatic condition. Therefore, an understanding of the physiological basis of yield formation can be of great help in selecting high-yielding stable cultivars for a

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region. However, little information is available on the production physiology of recent high-yielding cultivars of mustard under organic conditions. Therefore, the present study was attempted to analyzethe physiological basis of variation in growth and yield of popular mustardvarieties under the agro-climatic conditions of North-Western Indo-Gangetic Plains of Uttar Pradesh.

MATERIAL AND METHODS

Field experiments were conducted at ICAR-IIFSR, Modipuram (UP), India ($29^0$4' N latitude, $77^0$5' E longitude, and 230 m AMSL) during 2013-14 and 2014-15. The sub-tropical semi-arid climate of Modipuram is characterized by hot summers, cold winters with about 800 mm of average annual rainfall, and nearly 1600 mm of potential evapotranspiration. The soil was Typic Ustochrept, deep sandy loam, and slightly saline (*p*H 8.2).The experiment was conducted inrandomized block design with three replications.There are12 mustard varieties viz., DRMRIJ-31, NRCDR-02, NRCHB-101, NRCHB-506, Pusa Mustard-25, Pusa Mustard-26, Pusa Tarak, RH-406, RGN-229, RGN-48, Urvashi, and Pusa Bold were used as treatments. Each year, the crop was sown during the third week of October at a spacing of 45 cm x 10 cm by maintaining a gross plot area of 5.0 m x 4.0 m. In addition, farmyard manure, vermicompost, and neem cake were applied equivalent to the recommended dose of nitrogen (120 kg N ha^{-1})for nutrient management. In addition, seed treatment with bioagents like *Pseudomonas fluorescence*and *Trichoderma harzianum*at 4 g kg^{-1} of seed was done as prophylactic plant protection measures. A total of three irrigations were applied at critical stages, and weeding was done manually.

The observation on leaf area and photosynthetic rate were measured on three randomly sampled plants from each plot at 30, 60, and 90 days after sowing (DAS).A LA211 leaf area meter was used for leaf area measurement. Based on leaf area,the leaf area index (LAI) was calculated as the ratio of leaf area to the ground area covered by plants. The net photosynthetic rate was measured on fully expanded uppermost leaves using Li6200 Portable Photosynthesis System between 10:00-11:00 am. Total chlorophyll content in leaves was estimated by following Arnon, (1949). Crop growth rate (CGR) between 30-40 DAS and 80-90 DAS was calculated following Watson *et al., (*1952),based on the oven-dry weight of five randomly selected plants from each plot. At harvest, the number of primary and secondary branches of five tagged plants was counted separately, summed, and finally,the mean was taken. Seed, stover, and biological yield were obtained from a segmented area of 2 m × 2 m of each plot by leaving border rows.The entire above-ground biomass obtained from each net plot was sundried properly, and weight was recorded as biological yield. The seed yield for each net plot was deducted from the respective biological yield, and thus the stover yield was computed.Harvest index was calculated asseed yield as parentage of biological yield.The collected data were analyzed statistically through the SPSS software package applying the ANOVA technique. For multiple comparisons of the means of different parameters, Tukey's HSD test was used at a 5% probability level. Pearson's correlation coefficient (r) between grain yield and crop physiological parameters was calculated at 5% and 1% probability levels.

RESULTS AND DISCUSSION

Physiological parameters

A significant periodic variation in physiological parameters viz., LAI, photosynthesis rate, and chlorophyll content of leaves of mustard varieties was observed at 30, 60, and 90 DAS.The LAI, photosynthesis rate, and chlorophyll content increased with increasing rate up to 60 DAS, i.e., at peak flowering stage, and then it increased with decreasing rate. (Table 1). Varieties NRCHB-506, RH-406, and RGN -229, being at par, registered significantly maximum LAI in the range of 2.0-2.1 at 30 DAS, 3.9-4.0 at 60 DAS, and 3.1-3.2 at 90 DAS. The photosynthesis rate in varieties NRCHB-506, RH-406, and RGN -229 were 23.0-23.5 µmol $m^{-2}S^{-1}$ at 30 DAS, 26.7-27.3µmol $m^{-2}S^{-1}$ at 60 DAS, and 19.2-19.8µmol $m^{-2}S^{-1}$ at 90 DAS. Similarly, varieties NRCHB-506, RH-406, and RGN -229 recorded significantly higher values of chlorophyll content in the range of 0.81-0.86 mg g^{-1}at 30 DAS, 2.10-2.25 mg g^{-1}at 60 DAS, and 1.46-1.54 mg g^{-1}at 90 DAS. The minimum values of LAI were registered in NRCDR-02, while minimum

Table 1: Periodical variations in LAI, photosynthesis rate, chlorophyll content, and crop growth rateamong the mustard varieties

Varieties	LAI			Net Photosynthesis rate (µmol $m^{-2}S^{-1}$)			Chlorophyll content (mg g^{-1} fresh leaf)			CGR (g m^{-2} day^{-1})	
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30-40 DAS	80-90 DAS
DRMRIJ- 31	1.7^{bcd}	3.7^{cde}	2.9^{cde}	22.7^{gh}	26.4^{def}	18.9^{de}	0.74^{a}	2.01^{bc}	1.31^{a-d}	9.0^{ab}	5.0^{b}
NRCDR- 02	1.6^{ab}	3.5^{abc}	2.7^{ab}	22.1^{fg}	26.0^{c-f}	18.2^{cde}	0.76^{ab}	2.02^{bcd}	1.24^{ab}	10.0^{bcd}	6.4^{de}
NRCHB- 101	1.7^{bcd}	3.7^{de}	2.8^{bcd}	18.7^{a}	22.2^{a}	14.8^{a}	0.72^{a}	1.85^{a}	1.28^{abc}	8.1^{a}	4.4^{a}
NRCHB- 506	2.0^{ef}	3.9^{fgh}	3.1^{fgh}	23.0^{gh}	26.7^{ef}	19.2^{de}	0.81^{cd}	2.10^{cde}	1.46^{def}	10.2^{cd}	6.5^{e}
Pusa Mustard -25	1.7^{bc}	3.7^{bcd}	2.8^{bc}	19.7^{bc}	23.3^{ab}	15.6^{ab}	0.75^{a}	2.00^{bc}	1.21^{a}	9.1^{abc}	5.3^{b}
Pusa Mustard- 26	1.6^{ab}	3.5^{ab}	2.7^{ab}	18.9^{ab}	22.0^{a}	15.6^{ab}	0.72^{a}	1.93^{ab}	1.21^{a}	9.0^{abc}	5.3b
Pusa Tarak	1.5^{a}	3.4^{a}	2.6^{a}	19.9^{c}	23.5^{ab}	15.9^{ab}	0.73^{a}	1.93^{ab}	1.20^{a}	9.8^{bcd}	5.8^{c}
RH- 406	2.1^{ef}	4.0^{gh}	3.2^{gh}	23.5^{h}	27.3^{f}	19.8^{e}	0.83^{cd}	2.25^{f}	1.54^{f}	10.7^{d}	6.9^{f}
RGN- 229	2.1^{f}	4.0^{h}	3.2^{h}	23.1^{h}	26.9^{f}	19.8^{e}	0.86^{d}	2.18^{ef}	1.53^{ef}	10.5^{d}	6.6f
RGN- 48	1.9^{de}	3.9^{e-h}	3.0^{def}	21.6^{ef}	25.3^{cde}	17.8^{cd}	0.80^{bc}	2.10^{cde}	1.38^{b-e}	9.8^{bcd}	6.1^{cde}
Urvashi	1.9^{de}	3.8^{efg}	3.1^{efg}	20.4^{cd}	24.6^{bc}	16.6^{bc}	0.81^{cd}	2.07^{cd}	1.38^{b-e}	9.9^{bcd}	6.0^{cd}
Pusa Bold	1.8^{cd}	3.8^{def}	3.0^{def}	21.1^{de}	25.0^{cd}	17.7^{cd}	0.79^{bc}	2.14^{de}	1.40^{c-f}	9.7^{bcd}	5.9^{c}

Means superscripted with different lowercase letters (a–f) within a column are significantly different at $p \leq 0.05$ as per Tukey's HSD test

photosynthesis rate and chlorophyll content at all the growth stages were observed in NRCHB-101. The higher values of physiological parameters were due to the emergence and enlargement of new branches and leaves up to the peak flowering stage. Still,it decreased gradually with the senescence of leaves. The genetic makeup of the varieties significantly influenced the physiological parameters, probably by improving the photosynthetic production efficiency of leaves.

Table 2: Growth, yields attributes, and yield of mustard varieties

Varieties	Primary Branches $plant^{-1}$	Secondary Branches $plant^{-1}$	No. of silique $plant^{-1}$	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest Index (%)
DRMRIJ- 31	3.8^{ab}	10.2^{a}	218.4^{a}	1.42^{a}	6.02^{abc}	19.1^{a}
NRCDR- 02	3.5^{a}	14.9^{bc}	242.2^{cd}	1.67^{abc}	5.85^{abc}	22.2^{cd}
NRCHB- 101	4.2^{abc}	13.6^{b}	213.5^{b}	1.57^{abc}	5.59^{a}	21.9^{c}
NRCHB- 506	4.6^{bc}	17.5^{cde}	266.5^{def}	1.83^{bcd}	6.96^{cd}	20.8^{b}
Pusa Mustard -25	5.8^{e}	14.0^{b}	225.8^{bc}	1.58^{abc}	5.63^{ab}	21.9^{c}
Pusa Mustard- 26	5.7^{e}	16.8^{bcd}	230.8^{bc}	1.60^{abc}	5.73^{ab}	21.8^{c}
Pusa Tarak	4.2^{abc}	19.8^{de}	226.8^{bc}	1.54^{ab}	6.09^{abc}	20.2^{b}
RH- 406	4.7^{cd}	20.5^{e}	279.3^{f}	1.97^{d}	7.26^{d}	21.3^{c}
RGN- 229	4.7^{cd}	19.5^{de}	270.0^{ef}	1.91^{cd}	7.23^{d}	20.9^{b}
RGN- 48	5.0^{cde}	17.5^{cde}	228.5^{bc}	1.80^{bcd}	6.69^{a-d}	21.2^{bc}
Urvashi	4.6^{bc}	16.7^{bcd}	251.3^{cde}	1.87^{bcd}	6.77^{bcd}	21.6^{c}
Pusa Bold	5.5d^{e}	18.7^{de}	275.2^{ef}	1.79^{bcd}	7.75^{d}	18.8^{a}

Means superscripted with different lowercase letters (a–f) within a column are significantly different at $p \leq 0.05$ as per Tukey's HSD test

The CGR increased considerably up to 30–40 days coinciding with the period of increasing LAI and then decreased laterin all the varieties due to the natural senescence of lower leaves (Table 1). During 30-40 DAS, maximum CGR (10.7 g $m^{-2}day^{-1}$) was observed with RH-406 followed by RGN-229, and the lowest CGR (8.1 g $m^{-2}day^{-1}$) was recorded with NRCHB-101. Similar results were observed in CGR during 80-90 DAS. The significant improvement in CGRin varieties RH-406and RGN-229might have been due tohigher plant height and dry matter accumulationthan other varieties. CGR measures the dry matter accumulation per unit time, and it is a reasonable approximation of the canopy photosynthetic rate per unit ground area.

In the varieties NRCHB-506, RH-406 and RGN-229, the photosynthesis rate was also higher than the other varieties at all the growth stages (Table 1). Thus, significantly higher CGR was recorded in the varieties with higher LAI and a higher rate of photosynthesis.The supply of nutrients in balanced and optimum amounts stimulates crop growth throughthe enlarged leaf canopy and greater leaf expansion rate, as evidenced by greater LAI..The LAI at each stage has the significant positive correlation with photosynthesis rate (r= 0.609** at 30 DAS, r= 0.698** at 60 DAS, r= 0.641** at 90 DAS). Besides chlorophyll content at each stagehave the significant positive correlation with photosynthesis rate (r= 0.647**at 30 DAS, r= 0. 626** at 60 DAS, r= 0.711** at 90 DAS). The CGR at 30-40 DAS and 80-90 DAS was found significantly and positively correlated with the LAI, photosynthesis rate, and chlorophyll content at 30 DAS and 60 DAS, respectively (Table 3).

Crop growth and yield

The growth parameters *viz.,* the number of primary and secondary branchesplant^{-1} significantly differed among the varieties (Table 2). Across the varieties,the number of primary branchesplant^{-1}was ranged from 3.5 to 5.7, and the number of secondary branches plant^{-1}from 10.2 to 20.5.Varieties,Pusa Mustard-25 (5.8) and Pusa Mustard-26 (5.7) being at par with Pusa Bold and RGN-48 recorded the significantly higher number of primary branchesplant^{-1}. However, a significantly highest number of secondary branchesplant^{-1}were recorded in varieties, Pusa Tarak, RH-406, and RGN-229. The lowest numbers of primary and secondary branches were recorded in DRMRIJ-31 and NRCDR-02. The advantage gained in biomass production due to higher physiological parameters like LAI, photosynthetic rate, and chlorophyll content might be the plausible reason for the higher number of secondary branches in verities RH-406 and RGN-229. A significant positive correlation between CGR during 80-90 DAS with secondary branchesplant^{-1}(r= 0.603**) and siliqueplant^{-1}(r= 0.600**) were observed. The number of silique plant^{-1} as yield attributing characterdiffered significantly among the varieties (Table 2). Across the varieties, the number of siliqueplant^{-1} ranged from 218.4 to 279.3. Varieties NRCHB-506, RH-406, RGN-229, and Pusa Bold,being at par, recorded a significantly higher number of siliqueplant^{-1}compared with other varieties. The lowest number of siliqueplant^{-1}was recorded in DRMRIJ-31. The higher number of silique was perhaps due to more number of branchesplant^{-1}. The number of siliqueplant^{-1}was also found positively correlated with secondary branchesplant^{-1}(r= 0.683**). Besides, the nutrients available in the soil during the developmental stages determined the number of siliqueplant^{-1}. The findings are in agreement with the data obtained by Mandal and Sinha (2002).

The differences in physiological parameters, growth, and yield attributes led to significant differences in the seed yield, stover yields, and harvest index among different varieties (Table 2). Variety RH-406being statistically at par with NRCHB 506, RGN 229, RGN 48, Urvashi, and Pusa Bold recorded significantly higher seed yield (1.97 t ha^{-1}) compared to other varieties. Similar trends in varieties were observed in terms of stover yield also. This indicatesthat applying organic manures equivalent to a 100% recommended dose of nitrogen (120 kg ha-1) can yield better varieties with inherent superior physiological parameters. However, the role of growth and yield components is crucial in determining the seed yield of a crop. The seed yield was found significantly and positively correlated with CGR at 80-90 DAS (r=0.600**), chlorophyll content at 90 DAS (r=0.558**) and siliqueplant^{-1}(r=0.518**).Harvest index of different varieties ranged from18.8 to 22.2. This indicates that only about one-fifth of total dry matter was partitioned into seed yield. The harvest index was found significantly and positively correlated with seed yield (r= 0.590**).

Crop yield is the outcome of thecrop's genetic potential and agronomic management, of which nutrient management is foremost. Under similar management of nutrients, the yield difference isthe sole expression of the genetic potential of varieties. Under organic nutrient management with the slow and continuoussupply of essential elements to plant, the availability, acquisition, mobilization, and influx of nutrients into plant tissues increased and thus improved growth attributes, yield components, harvest index, and yield. This indicates that the organic nutrient management did not limit yield physiological parameters;

Table 3: Correlation coefficients (r) of various

	SY	STY	LAI_30 DAS	LAI_60 DAS	LAI_90 DAS	Pn_30 DAS	Pn_60 DAS	Pn_90 DAS	CGR_30-40 DAS	CGR_80-90 DAS	ChPC_30 DAS	ChPC_60 DAS	ChPC_90 DAS	PBP	SBP	SPP
SY	1															
STY	.289*	1														
LAI_30 DAS	.541**	.588**	1													
LAI_60 DAS	.568**	.570**	.918**	1												
LAI_90 DAS	.560**	.556**	.904**	.924**	1											
Pn_30 DAS	.280*	.481**	.609**	.580**	.540**	1										
Pn_60 DAS	.443**	.469**	.652**	.698**	.632**	.858**	1									
Pn_90 DAS	.389**	.508**	.692**	.705**	.641**	.854**	.922**	1								
CGR_30-40 DAS	.610**	.554**	.588**	.583**	.543**	.670**	.745**	.732**	1							
CGR_80-90 DAS	.600**	.449**	.564**	.598**	.536**	.522**	.747**	.733**	.894**	1						
ChPC_30 DAS	.459**	.601**	.695**	.718**	.703**	.647**	.603**	.564**	.709**	.525**	1					
ChPC_60 DAS	.477**	.566**	.618**	.598**	.564**	.738**	.626**	.608**	.681**	.479**	.760**	1				
ChPC_90 DAS	.558**	.592**	.825**	.833**	.828**	.555**	.705**	.711**	.650**	.636**	.663**	.563**	1			
PBP	.139	.151	.067	.134	.146	-.304**	-.292*	-.194	-.021	.018	.056	.040	.015	1		
SBP	.455**	.513**	.353**	.308**	.312**	.168	.252*	.280*	.636**	.603**	.434**	.375**	.423**	.210	1	
SPP	.518**	.630**	.548**	.533**	.506**	.320**	.381**	.412**	.708**	.600**	.615**	.584**	.533**	.284*	.683**	1
HI	.590**	-.593**	-.044	-.019	-.015	-.181	-.034	-.111	.039	.128	-.139	-.069	-.044	-.002	-.034	-.082

**Correlation is significant at the 0.05 level (2-tailed); **. Correlation is significant at the 0.01 level (2-tailed)*
SY- Seed yield. STY-Stover yield, LAI_30 DAS, LAI_60 DAS, LAI_90 DAS,
Pn (Photosynthesis rate)_30 DAS, Pn_60 DAS, Pn_90 DAS, CGR_30-40 DAS, CGR_80-90 DAS, ChPC (Chlorophyll content)_30 DAS, ChPC_60 DAS, ChPC_90 DAS, PBP- Primary branches plant^{-1}, SBP- Secondary branches plant^{-1}, SPP- Siliqua plant^{-1}

parameters; growth and yield attributes and stover yield with seed yield of mustard formation,as indicated by a higher rate ofphotosynthesis, biomass production, and seed yield. The conducive effect of organic manures could be attributed to the supply of nutrients through mineralization and improvement of the physicochemical properties of the soil (Kumar and Singh, 2019).

From the present study, it is inferred that slow nutrient supply through organic sources did not limit yield formation as indicated by higher leaf area, photosynthetic rate, and chlorophyll content in varieties like RH-406, RGN-229, and NRCHB-506. These varieties, through their physiological advantage, support higher biomass production and seed yield of mustard. Hence varieties like RH-406, RGN-229, and NRCHB-506 may be advocated to sustain the higher productivity of mustard under organic nutrient management in North-Western Indo-Gangetic Plains of Uttar Pradesh.

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