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Correlation Studies of Morpho-physiological Characters with Seed Yield in Rapeseed (*Brassica rapa* var. Toria)

Rajesh Chintey[1], Ratna Kinkor Goswami[2], Bhagawan Bharali[1], Ranjan Das[1], Ramani Kanta Thakuria[3], Raju Prasad Paswan[4], Pankaj Kumar Debchoudhury[5], Lolesh Pegu[6], Dipankar Sonowal[7]

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ABSTRACT

Background: In the North-Eastern states, Assam has the highest area of cultivation of rapeseed and found to be potential hub for increasing productivity to a great extent. To fulfil the increasing demand for edible oils, interdisciplinary approaches including physiological parameters must be paid off. The suitable genotype for a particular region has to be identified based on physiological efficiency and yield.

Methods: A field experiment was carried out at the Instructional-cum-Research (ICR) Farm, Assam Agricultural University, Jorhat-13, Assam during *rabi* seasons of 2021-22 and 2022-23. The experiment was laid out in randomized block design with three replications comprising of 22 different genotypes of rapeseed including TS-38 (Check), TS-46, TS-67, TS-36, TS-29, TS-75-1, TS-75-1TL, TS-75-2ME, TS-75-2-MM, TS-76-1, TS-76-2, JT-90-1, Panchali, Bhawani, CG Toria-4, TKM-20-1, TKM-20-2, JT-14-5, PT-2018-09, CG Toria-3, Tapeshwari and PT-303. The crops were grown following the recommended package of practices. All the morpho-physiological parameters, yield attributes and yield were recorded following the standard methodologies. The correlation coefficients of morpho-physiological characters and different yield components with seed yield were worked out from the pooled values of two years following the standard method.

Result: The results indicated that number of green leaves per plant, stem diameter, total dry weight, total leaf chlorophyll content, AGR and CGR showed highly significant positive correlation with seed yield, clearly indicating their contribution towards higher yield in rapeseed. The number of primary branches and SLW exhibited significant positive correlation with seed yield. Among the yield attributes, number of siliqua per plant, seeds per silique, seeds per plant, sink capacity, stover yield and harvest index showed a highly significant positive correlation with the seed yield.

Key words: Genotypes, Morphological parameters, Rainfed, Rapeseed.

INTRODUCTION

Rapeseed (*Brassica rapa* var. Toria) belongs to genera Brassica, species rapa with chromosome number of 2n=20 (Mahendra *et al*., 2020). It is a short duration, self-pollinated and long day crop. Toria is characterized by hollow, weak stem, shallow roots with less biological yield, but high harvest index. The crop is one of the most popular and widely used oil seed crops among the people of Assam and North-East India. It contains 33-45% oil, 18-36% protein and other important fatty acids like linolenic acid, oleic acid, etc. It is also used as vegetable, edible oil, spices, preservatives, seed meal, fertilizer and feed. The average area, production and productivity of rapeseed in India during the period from 2017-18 to 2021-22 is 67.30 lakh hectares, 97.96 lakh tones and 14.56 quintal, respectively (Anonymous, 2023). In Assam, the crop accounts for nearly one-third of the oil produced in India, making the state as country's key edible oilseed producer. The total area under rapeseed in Assam is 2.89 lakh hectares with a total production of 1.86 lakh tones and the productivity is 6.44 quintal per hectare (Anonymous, 2022). In the North-Eastern states, Assam is the highest in terms of area of cultivation of rapeseed and has the potential to increase productivity to great extent (Deka *et al*., 2018). To fulfil the increasing demand of edible oils, appropriate interventions must be paid for improvement of existing oilseed

[1]Department of Crop Physiology, Assam Agricultural University, Jorhat-785 013, Assam, India.
[2]Department of Crop Physiology, Biswanath College of Agriculture, Assam Agricultural University, Biswanath Chariali-785 013, Assam, India.
[3]Horticultural Research Station, Assam Agricultural University, Kahikuchi-781 017, Guwahati, Assam, India.
[4]Department of Agricultural Statistics, Assam Agricultural University, Jorhat-785 013, Assam, India.
[5]Zonal Research Station, Assam Agricultural University, Shillongani, Nagaon-782 001, Assam, India.
[6]Department of Crop Physiology, Sarat Chandra Sinha College of Agriculture, Assam Agricultural University, Rangamati, Dhubri-785 013, Assam, India.
[7]Department of Soil Science, Assam Agricultural University, Jorhat-785 013, Assam India.

Corresponding Author: Rajesh Chintey, Department of Crop Physiology, Assam Agricultural University, Jorhat-785 013, Assam, India. Email: rajesh95chintey@gmail.com

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genotypes, introduction of new species or varieties. The suitable genotype for a particular region has to be identified based on morpho-physiological efficiency and higher productivity. The important morpho-physiological parameters, such as leaf area index (LAI), absolute growth rate (AGR), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), specific leaf weight (SLW), total leaf chlorophyll, biomass, source-sink ratio, sink capacity, harvest index (HI) may contribute substantially for boosting up the productivity in rapeseed (Malek *et al.,* 2012 and Mondal *et al.,* 2020). Only a few research works on the existing rapeseed varieties with regard to physiological efficiency has been conducted. Indeed, there is a need to identify the most important morpho-physiological parameters which govern the productivity of rapeseed and to find out the relationships among different morpho-physiological characters and yield attributes with seed yield through correlation studies. Keeping these points in view, the present study was conducted.

MATERIALS AND METHODS

The present experiment was carried out at the Instructional-cum-Research (ICR) Farm, Assam Agricultural University, Jorhat-13, Assam, during *rabi* seasons of 2021-22 and 2022-23. The experimental farm is situated at 26°47 N latitude and 94°12 E longitudes at an elevation of 86.6 m above mean sea level (MSL). The climate of experimental site of Assam Agricultural University, Jorhat is characterized by subtropical, humid climate with dry summer and cold winter. The soil of the experimental plot was sandy-loam, acidic pH with medium levels of N, P and K. The seeds were collected from the Zonal Research Station, AAU, Shillongani, Nagaon, Assam. The experiment was laid out in randomized block design with 3 replications and the crops were raised following the recommended package of practices. The statistical analysis was done by the method of Panse and Sukhatme (1967). The data of both the years were pooled and correlation of different parameters was analysed with seed yield per plant.

Morphological parameters

Five numbers of plants (avoiding the boarder rows) were randomly selected from each replication, tagged and all the data related to morpho-physiological parameters, yield attributes and yield were taken from these plants and average values were computed.

Plant height was measured at harvest from the ground level upto the tip of the upper most leaf using meter scale. The number of primary branches at harvest was recorded. The number of young, actively growing green leaves was counted from the base to the top of the plant at 60 DAS. Newly emerging underdeveloped young leaves and senesced leaves were avoided. Root volume was measured at harvest by water displacement technique using measuring cylinder (Bohm, 1979).

For stomatal index (SI), fresh leaf samples were collected from field and brought to the laboratory. Selected parts of the leaves were pained using light coloured nail polish on both the sides. Then on cello tape was pressed. After pressing the tape for some time, it was removed from the leaf. The cello tape was then put on a slide and observed under a microscope. Micrographs were captured from various regions of the sections using different magnifications through mobile camera. Stomatal density (No. mm^{-2} of leaf area) on abaxial and adaxial surfaces of the leaf was counted. Stomatal index was calculated according to the method of Meidner and Mansfield (1968) using the following formula:

$$SI\ (\%) = \frac{SD}{ED+SD} \times 100$$

Where:
SI= Stomatal index.
SD= Stomatal density.
ED= Epidermal pore density.

Morpho-physiological growth parameters

Absolute growth rate (AGR) was calculated by using the formula given below (Hunt, 1978):

$$AGR = \frac{W_2-W_1}{T_2-T_1}$$

Where:
W_1 and W_2 = Total dry weights per plant in g at time T_1 and T_2 respectively.

Crop growth rate (CGR) was calculated by the formula given below (Hunt, 1978):

$$CGR = \frac{W_2-W_1}{T_2-T_1} \times \frac{1}{\rho}$$

Where:
W_1 and W_2= Whole plant dry weight at time T_1 and T_2 respectively.
ρ = Ground area in m^2 on which W_1 and W_2 are recorded.

Relative growth rate (RGR) was calculated by the formula given below:

$$RGR = \frac{\log W_2 - \log W_1}{\log T_2 - \log T_1}$$

Where:
W_1 and W_2 = Total dry weights per plant in g at time T_1 and T_2 respectively.

The specific leaf weight (SLW) includes the leaf thickness and it was determined as per the formula of Radford (1967):

$$SLW = \frac{\text{Leaf dry weight (mg)}}{\text{Leaf area (cm}^2\text{)}}$$

Leaf area index (LAI) was calculated using the formula of Watson (1952) as follows:

$$LAI = \frac{\text{Leaf area/plant}}{t}$$

Net assimilation rate (NAR) is the rate of dry weight increase per unit leaf area per unit time. It was calculated by the formula of Radford (1967).

$$NAR = \frac{W_2-W_1}{T_2-T_1} \times \frac{\log L_2-\log L_1}{L_2-L_1}$$

Where:

W_1 and W_2 = Total dry weights per plant in g at time T_1 and T_2 respectively.

L_1 and L_2 = Leaf area (dm^2) at T_1 and T_2 respectively.

Sink capacity was calculated from numbers of siliqua per meter square, seed per pod and individual seed weight using formula as suggested by McGuire and Thurling, (1992). Stover yield was calculated by harvesting all the plants from 1 m^2 at physiological maturity from each plot and after proper drying seeds were separated and stover yield was recorded and converted into kg ha^{-1}.

Biochemical parameters

Leaf chlorophyll content was estimated after extracting by non-maceration method using Dimethyl Sulphoxide (DMSO) (Hiscox and Israelstam, 1979). Leaf proline content was estimated by the methodology of Bates *et al*. (1973). The nitrate reductase activity (NRA) *in vivo* was assayed by the method of Saradhambal *et al*. (1978). The oil extraction was done according to official methods of Januszewska *et al*. (1999) using soxhlet apparatus. Protein was estimated by using Bradford's method (1976).

Yield and yield attributing parameters

The number siliqua per plant was counted from five tagged plants randomly selected in each replication and average value was calculated. The number of seeds per silique and siliqua length was measured from ten randomly selected siliquae and average values were computed. The number of seed per plant was calculated by multiplying the average number of silique per plant with number of seeds per silique. The seeds from five plants were dried and weighed to record the seed yield per plant.

Correlation coefficients were calculated between seed yield and yield components and seed yield with important morpho-physiological parameters following the method of Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

The data for correlation studies of morpho-physiological parameters with seed yield presented in Table 1 indicated that number of green leaves per plant, stem diameter, total dry weight, total leaf chlorophyll content, AGR and CGR showed highly significant positive correlation with seed yield while, number of primary branches and SLW exhibited significant positive correlation with seed yield. Total dry weight had highly significant positive correlation with total chlorophyll content, AGR and CGR. Likewise green leaf number showed high positive correlation with total dry weight, total chlorophyll content, CGR and RGR. Stem

Table 1: Correlation of different morphological, physiological, biochemical and quality parameters with seed yield in rapeseed.

	YPH	P.HT	BRN	LFN	STDM	TDWT	DRN	CHL	AGR	CGR	RGR	SLW	LAI	NAR	RTVM	SI	PRLC	NRA	OLCT	PRTC
YPH	1.000																			
P.HT	-0.076^{NS}	1.000																		
BRN	0.447*	-0.082^{NS}	1.000																	
LFN	0.728**	-0.103^{NS}	0.488*	1.000																
STDM	0.605**	0.365^{NS}	0.416^{NS}	0.448*	1.000															
TDWT	0.841**	-0.156^{NS}	0.541**	0.720**	0.624**	1.000														
DRN	-0.012^{NS}	-0.040^{NS}	0.372^{NS}	-0.008^{NS}	-0.160^{NS}	-0.207^{NS}	1.000													
CHL	0.663**	-0.239^{NS}	0.433*	0.802**	0.325^{NS}	0.687**	0.024^{NS}	1.000												
AGR	0.632**	0.367^{NS}	0.362^{NS}	0.558**	0.784**	0.572**	-0.049^{NS}	0.553**	1.000											
CGR	0.660**	0.379^{NS}	0.384^{NS}	0.576**	0.811**	0.593**	-0.054^{NS}	0.555**	0.996**	1.000										
RGR	0.365^{NS}	0.438*	0.187^{NS}	0.404^{NS}	0.668**	0.292^{NS}	0.196^{NS}	0.364^{NS}	0.758**	0.776**	1.000									
SLW	0.483*	-0.177^{NS}	0.110^{NS}	0.343^{NS}	0.254^{NS}	0.545**	-0.487*	0.467*	0.376^{NS}	0.376^{NS}	0.003^{NS}	1.000								
LAI	0.203^{NS}	0.098^{NS}	0.097^{NS}	-0.009^{NS}	0.129^{NS}	-0.012^{NS}	-0.111^{NS}	-0.164^{NS}	0.049^{NS}	0.079^{NS}	-0.074^{NS}	-0.030^{NS}	1.000							
NAR	0.403^{NS}	0.043^{NS}	0.048^{NS}	0.398^{NS}	0.450*	0.417^{NS}	-0.153^{NS}	0.530*	0.710**	0.690**	0.502*	0.500*	-0.302^{NS}	1.000						
RTVM	0.186^{NS}	-0.028^{NS}	0.244^{NS}	0.143^{NS}	0.067^{NS}	0.112^{NS}	0.142^{NS}	-0.067^{NS}	-0.013^{NS}	0.002^{NS}	-0.014^{NS}	-0.473*	0.403^{NS}	-0.392^{NS}	1.000					
SI	0.276^{NS}	0.195^{NS}	0.155^{NS}	0.083^{NS}	0.409^{NS}	0.458*	-0.031^{NS}	0.143^{NS}	0.289^{NS}	0.295^{NS}	0.232^{NS}	0.185^{NS}	0.076^{NS}	0.230^{NS}	-0.076^{NS}	1.000				
PROL	0.245^{NS}	0.180^{NS}	0.021^{NS}	0.048^{NS}	0.248^{NS}	0.217^{NS}	0.024^{NS}	-0.037^{NS}	0.046^{NS}	0.060^{NS}	-0.051^{NS}	-0.011^{NS}	-0.143^{NS}	-0.060^{NS}	0.022^{NS}	0.352^{NS}	1.000			
NRA	0.168^{NS}	-0.069^{NS}	0.420^{NS}	0.111^{NS}	0.020^{NS}	0.075^{NS}	0.443*	0.092^{NS}	0.125^{NS}	0.107^{NS}	-0.091^{NS}	0.059^{NS}	0.025^{NS}	-0.041^{NS}	0.192^{NS}	-0.001^{NS}	0.090^{NS}	1.000		
OLCT	0.170^{NS}	0.215^{NS}	0.389^{NS}	0.430*	0.140^{NS}	0.351^{NS}	-0.100^{NS}	0.381^{NS}	0.186^{NS}	0.187^{NS}	0.028^{NS}	0.202^{NS}	-0.351^{NS}	0.013^{NS}	0.072^{NS}	0.089^{NS}	0.156^{NS}	0.306^{NS}	1.000	
PRTC	-0.137^{NS}	0.299^{NS}	0.216^{NS}	-0.021^{NS}	-0.074^{NS}	-0.022^{NS}	0.199^{NS}	0.045^{NS}	-0.189^{NS}	-0.155$_{NS}$	0.072^{NS}	-0.247^{NS}	-0.069^{NS}	-0.346^{NS}	0.078^{NS}	0.156^{NS}	0.165^{NS}	-0.035^{NS}	0.251^{NS}	1.000

Table 2: Correlation of yield attributes with seed yield in rapeseed.

	YIELD	SLPP	SLL	SPSL	STS	SPP	SC	STY	HI
YIELD	1.000								
SLPP	0.674**	1.000							
SLL	0.091^{NS}	-0.355^{NS}	1.000						
SPSL	0.681**	0.245^{NS}	0.271^{NS}	1.000					
STS	0.252^{NS}	0.054^{NS}	0.306^{NS}	-0.045^{NS}	1.000				
SPP	0.813**	0.912**	-0.182^{NS}	0.608**	0.003^{NS}	1.000			
SC	0.942**	0.801**	-0.016^{NS}	0.598**	0.374^{NS}	0.882**	1.000		
STY	0.716**	0.393^{NS}	0.155^{NS}	0.707**	0.238^{NS}	0.594**	0.666**	1.000	
HI	0.793**	0.684**	-0.075^{NS}	0.302^{NS}	0.174^{NS}	0.680**	0.786**	0.204^{NS}	1.000

^{NS}Non-significant, *Significant at 5%, **Significant at 1%.

SLPP: Siliquae per plant; CGR: Crop growth rate; SLL: Siliqua length; RGR: Relative growth rate; SPSL: Seeds per silique; SLW : Specific leaf weight; TSW: Thousand seed weight; LAI: Leaf area index; SPP: Seeds per plant; NAR: Net assimilation rate; SC: Sink capacity; RTVM: Root volume; STY: Stover yield; SI: Stomatal Index; HI: Harvest index; PRLC: Proline content; YPH: Yield per hectare; PRTC: Protein content; P.HT: Plant height; NRA: Nitrate reductase activity; BRN: Branch number; OLCT: Oil content; LFN: Leaf number; STDM: Stem diameter; TDWT: Total dry weight; DRN: Duration; CHL: Chlorophyll; AGR: Absolute growth rate.

diameter was found to have high positive correlation with total dry weight, AGR, CGR and RGR.

The correlation studies of seed yield with yield components presented in Table 2 indicated that siliquae per plant, seeds per siliquae, seeds per plant, sink capacity, stover yield and harvest index had high positive significant correlation with seed yield. It was also observed that silique per plant had significant positive correlation with seed per plant and sink capacity. Seed per siliqua had significant positive correlation with seed per plant, sink capacity and stover yield.

The findings of Rashid *et al*. (2010) was also similar with our result who reported that leaf area index (LAI), crop growth rate (CGR) and total plant dry matter accumulation had a positive significant correlation with seed yield in rapeseed (*Brassica campestris* L). An evaluation of correlation coefficients by Khayat *et al.* (2012) forwarded the idea that the total dry matter, harvest index, 1000- grain weight, the number of grains per pod, number of pods per plant and plant height had positive significant correlation with grain yield in *Brassica napus* (canola), which corroborates with the results of our experiment.

Ahmadzadeh *et al*. (2019) also found similar results in rapeseed where they concluded that biomass, number of pods per branch and number of branches had high degree of positive significant correlation and high direct effect on grain yield. Mondal *et al.* (2020) reported that in high yielding mutants of rapeseed, the seed yield had significant positive correlation with branch number, total dry matter and leaf chlorophyll content which is similar with the results of the present study. Li *et al.* (2023) reported that plant biomass, siliqua number per plant, and seed yield showed a significant positive correlation with each other which is also same with the results of the present study.

The correlation studies showed a highly positive correlation of different morpho-physiological parameters *viz*., number of green leaves per plant, stem diameter, total dry weight, total leaf chlorophyll content, AGR and CGR with seed yield. Among the yield attributes, number of siliqua per plant, seeds per silique, seeds per plant, sink capacity, stover yield and harvest index were found to contribute significantly to higher yield in rapeseed. In this context, the above parameters may be regarded as the physiological indices for higher productivity in rapeseed.

CONCLUSION

The results indicated that number of green leaves per plant, stem diameter, total dry weight, total leaf chlorophyll content, AGR and CGR showed highly significant positive correlation with seed yield, which clearly indicate their contribution towards higher yield in rapeseed. The number of primary branches and SLW exhibited significant positive correlation with seed yield. Among the yield attributes, number of siliqua per plant, seeds per silique, seeds per plant, sink capacity, stover yield and harvest index showed a highly significant positive correlation with the seed yield. However, further detailed research need to be done for a stronger conclusion.

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