

Genotypic variation for nitrogen-use efficiency in rapeseed-mustard

PK Barua*, J Chutia, P Borah and M Barua

Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat 785013, Assam, India

*Corresponding author: purna.barua@aaau.ac.in

(Received: 15 July 2023; Revised: 11 December 2023; Accepted: 12 December 2023)

Abstract

Genetic variation for nitrogen-use efficiency (NUE) and related yield traits were assessed in 11 *toria* (*Brassica rapa* var. *toria*), 14 *yellow sarson* (*Brassica rapa* var. *yellow sarson*) and 7 Indian mustard (*Brassica juncea*) genotypes. These genotypes were evaluated at 0 and 40 kg N ha⁻¹ levels of nitrogen fertilization and, nitrogen-use efficiency (NUE) in terms of agronomic efficiency was determined. Significant genetic variation was observed for all the traits studied. A *toria* genotype TS65 produced the highest yield (9.92 q/ha) coupled with the highest NUE (17.5 kg kg⁻¹). High heritability was recorded for leaf nitrogen, 1000-seed weight, nitrate reductase activity (NRA), days to maturity, siliquae per plant and seeds per siliqua. High genetic advance was recorded for siliquae number per plant, NRA, seeds per siliqua and leaf N. There was strong positive genetic correlation between seed yield and NUE, indicating the significance of enhanced NUE for seed yield improvement.

Keywords: Genotypes, nitrogen-use efficiency, rapeseed-mustard, yield traits

Introduction

Oilseed brassicas comprising mainly rapeseed (*Brassica rapa* L.), Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] and oilseed rape (*Brassica napus* L.) are the third most important source of edible oils of the world after palm oil and soybean. Globally the production of oilseed brassicas is 88.8 million tonnes in 2022 from 41.9 million hectares (USDA, 2023). In India rapeseed-mustard is the second most important edible oilseed crop after soybean and accounts for nearly 28.4% of the total oilseeds produced in the country during 2020-21. India is the third largest producer of rapeseed-mustard after Canada and China, contributing to about 12.6% of world's total production from over a crop area of 6.7 million ha with production of 10.2 million tonnes during 2020-21 (Choudhary *et al.*, 2023). Indian mustard accounts for about 80% of rapeseed-mustard production. In Assam, rapeseed-mustard is the most important oilseed crop, grown in an area of 0.29 million ha with a production of 0.23 million tonnes resulting in only 773 kg/ha average yield, whereas, world average yield of rapeseed-mustard is 1978 kg/ha and Indian average yield of 1458 kg/ha (Anonymous, 2022).

In Assam *toria* is the predominant oilseed crop; traditionally preferred by the farmers for its short duration and ease of cultivation as rainfed crop in the short winter season. *Toria* accounts about 85% oilseeds area in Assam. The low productivity in the state is due to several reasons, low yield potential of *toria* and low plant nutrition are primary factors impacting plant growth, development and productivity. Nitrogen (N) is

one of the important major plants nutrients, which can be supplied externally through nitrogenous fertilizer. The N-use efficiency (NUE) of oilseed rape (*Brassica napus* L.) is very low (Schjoerring *et al.*, 1995), if high doses of N fertilizer is applied to increase the yield, it would lead to severe pollution of the environment, especially the soil through leaching loss and evaporation of volatile N compounds. Hence the best possible option is to improve NUE which would increase profitability not only through higher yields but also through reducing fertilizer application. NUE of a crop is determined by the harvestable dry matter yield (kg/ha), which is obtained per unit of available native and applied nitrogen (N). It is generally estimated in terms of seed yield produced per unit of supplied N (Moll *et al.*, 1982). N fertilizer required for oilseed rape production in the UK accounts for 79% of the greenhouse gas emission (Mahmuti *et al.*, 2009). Thus, improving NUE not only reduces the GHG emission but also it will reduce the risk of nitrate leaching by reducing the amount of fertilizer N that is not used by the crop. Genetic variation was observed in mustard for NUE both at normal and limited N supply (Jat and Choudhary, 2019). A significant positive relation between N uptake and seed yield was reported though N uptake and utilization efficiency reduced with increase in N uptake beyond 120 kg/ha under normal and 60 kg/ha under limited N supply. Therefore, screening of breeding materials for high NUE is of prime importance. The present study was made to assess genetic variation in a set of Indian rapeseed and mustard genotypes for NUE and related yield traits.

Materials and Methods

Total 32 genotypes of rapeseed-mustard consisting *toria* (11) and *yellow sarson* (14) and Indian mustard (7) were collected from Zonal Research Station, Assam Agricultural University, Shillongoni, Assam, ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur and ICAR-Indian Agricultural Research Institute, New Delhi. The experiment was laid out in a randomized block design with 2 replications at Assam Agricultural University, Jorhat (26°57'N latitude, 94°12'E longitude and 86.6 m above the msl). The soil of the experimental site was sandy loam in texture, the organic matter content was medium (0.54%) and native available N, P and K levels were 293.7, 13.8 and 82.6 kg/ha, respectively. The genotypes were grown at 0 and 40 kg/ha (recommended) of nitrogen fertilization. Urea was the source N fertilizer. Observations were recorded for plant height, leaf N%, nitrate reductase activity (NRA), numbers of siliquae per plant, number of seeds per siliqua and 1000-seed weight. The in-vivo estimation of NR activity in plants was based on conversion of nitrate to nitrite and inhibition of nitrite reduction to ammonia in anaerobic condition (Srivastava and Ormrod, 1984). Kjeldhal

method was used to determine leaf N content, which is based on catalytic conversion of organic nitrogen into ammonia and its subsequent estimation by acid base titration. Days to maturity was observed when more than 75% siliquae turned yellow to brown. Plot seed yield was recorded which was then converted to seed yield (q/ha). NUE was calculated as agronomic efficiency (kg seed yield per kg applied N) based on the formula given by Fageria and Baligar (2005).

Results and Discussion

Analysis of variance

Results for 40 kg/ha N are only presented as this is the recommended N dose for the crop. Results obtained at 0 kg/ha N was utilized to work out NUE only. Genotypes displayed significant variation (Table 1) for all the characters including NUE. Similarly high variation was observed between the groups *i.e.*, *toria* vs. mustard, *toria* vs. *yellow sarson* (YS), and YS vs. mustard for all the traits except for NUE indicating that NUE of the three groups were at par. Mustard and YS were also statistically equivalent for seed yield.

Table 1: Analysis of variance (mean squares) for NUE and yield attributes in rapeseed-mustard

Source	df	DM	PH	SQP	SSQ	TSW	Leaf N	NRA	NUE	SYH
Replications	1	0.3	15	10.6	0.2	0.0	0.0	143.0**	0.3	0.9
	3									
Genotypes	1	183**	534**	2818.7**	166.1**	0.7**	5.0**	1794.8**	20.9**	3.7**
<i>Toria</i> vs mustard	1	2764**	8094**	38153.2**	36.7*	1.0**	0.2*	12552.0**	0.1	10.1**
<i>Toria</i> vs YS	1	2632**	401**	7092.5**	1608.3**	2.3**	3.7**	4837.2**	0.0	8.1**
Mustard vs YS	1	105**	5858**	17085.8**	1700.3**	0.1**	4.6**	3190.2**	0.1	0.7
Error	3	1.5	61.7	93.5	6.0	0.0	0.0	14.3	4.8	0.5
CV%	1	1.2	7.8	10.4	9.8	1.8	3.5	4.8	20.5	9.2

Where; YS: Yellow sarson, DM: days to maturity, PH: plant height, SQP: number of siliquae per plant, SSQ: number of seeds per siliquae, TSW: thousand seed weight, NRA: nitrogen reductase activity, NUE: nitrogen-use efficiency, SYH: seed yield per ha

Mean performance

Mean performance of the genotypes (Table 2) revealed better expression of the characters at 40 kg N/ha than at 0 kg N/ha (data for N₀ not presented). As expected *toria* resulted the shortest (91.5 cm) plants, whereas mustard had the tallest (122.2 cm) plant types. Consequently, *toria* matured at the earliest (95.5 days) followed by YS (110.1 days) and then mustard (113.4 days). Though number of siliquae per plant (67.9), number of seeds per siliquae (20.4), thousand seed weight (3.7 g) in *toria* were less than that in YS (91.9, 31.8, 4.1 g, respectively). However, the seed yield was more in *toria* (8.1 q/ha) than the YS (7.2 q/ha) and mustard (7 q/ha). This might be due

to higher nitrogen reductase activity (NRA) in YS (81.5) and mustard (100) than *toria* (61.7). NRA leads to conversion of nitrate to organic form thereby making N unavailable to plant and N is an important component for accumulation of dry matter in the plant especially in the seed. Also leaf N content (5.5%) was more in *toria* than YS (5%) and at par with mustard (5.7%). Less number of seeds per siliquae (18.3) was also one of the reasons for less yield in mustard.

The *toria* genotype TS65 (Table 2) produced the highest seed yield (9.9 q/ha) coupled with the highest NUE (17.5 kg/kg). However, for seed yield, it was at par with six other genotypes, two of *toria*, three of YS and one of

mustard, and for NUE was at par with five genotypes of YS and three of mustard. TS65 was found to be an average performer for other yield attributes. Hence, it could be concluded that higher yield in TS65 was primarily due to higher NUE, indicating the significance of this trait in crop yield of oilseed brassicas. This observation was consolidated by Gan *et al.* (2008) who stated that all the oilseed species with higher yield had higher NUE and *vice-versa*. The mustard variety NRCHB-101 also produced higher yield (9.6 q/ha) with 14.5 kg/kg NUE and with the highest number of siliquae per plant (178 numbers). Other high yielders at par with TS65 were YSK-09-2, YSH-401, Benoy (*yellow sarson*), TS67 and TS60 (*toria*). Their NUE value was

in the range of 10-15%. MPJ-135, a mustard line with high number of siliquae per plant (178) and high NUE (15 kg/kg) produced average yield (7.9 q/ha). YSK-90-2 was the highest yielder (9.6 q/ha) among the *yellow sarson* genotypes with NUE of 14.3 kg/kg. As group the *toria* genotypes were higher yielders followed by the *yellow sarson* and mustard. However, there was no significant difference among them for NUE (10.8, 10.8, 10.7 kg/kg respectively for *toria*, *yellow sarson* and mustard). The other yield component traits augmented seed yield in them. Thus, these findings suggested the importance of these traits along with NUE. These genotypes could be used for crop improvement programme.

Table 2: Mean performance of rapeseed-mustard genotypes for NUE and yield attributes

Genotype	DM	PH (cm)	SQP	SSQ	TSW (g)	LeafN (%)	NRA (μ mol No ₂ /g FW/hr)	NUE (kg/kg)	SYH (q/ha)
TS36	98.5	77	67	16.7	3.7	5.1	81.7	11.5	8.5
TS38	96.5	79	42	25.5	3.8	2.8	54.4	6.7	7.3
TS46	90.5	100	56	15.2	2.7	6.5	87.1	11.7	7.5
TS50	95.5	93	64	27.2	3.7	4.4	29.6	12.1	8.1
TS60	91.5	76	67	21.5	3.8	6.1	27.6	11.7	8.8
TS62	98.0	96	72	15.5	3.9	4.0	49.2	5.8	6.4
TS64	98.5	89	66	25.0	3.8	5.9	48.0	12.1	8.8
TS65	97.0	105	51	17.7	3.5	5.2	55.5	17.5	9.9
TS66	92.0	111	58	18.4	3.8	7.0	74.8	9.5	7.0
JT90-1	94.0	100	112	21.0	3.6	5.8	113.8	10.1	7.6
TS67	98.0	82	94	20.7	4.3	8.0	57.0	10.0	8.8
Mean of <i>toria</i>	95.5	92	68	20.4	3.7	5.5	61.7	10.8	8.1
YSWR-2012	122.5	109	52	26.6	4.8	5.0	46.3	5.2	5.8
NRCYS-05-02	115.5	107	143	29.0	4.6	5.5	88.4	9.4	6.7
BENOY	115.5	89	81	28.0	3.9	5.4	85.2	11.7	8.8
PYS-2008-2	110.5	101	56	39.5	3.8	7.2	77.1	8.5	6.1
DRMRYS-09-103	107.0	102	74	38.2	3.9	4.1	58.3	10.4	6.3
YSH-401	105.0	89	83	33.0	4.6	4.1	121.3	15.0	8.8
DRMRYS-09-99	109.5	107	103	13.7	4.0	8.0	127.6	14.6	7.9
YSK-09-2	107.0	92	110	41.5	4.8	3.0	81.4	14.3	9.6
PTS-2007-7	107.5	96	71	38.5	4.1	4.3	71.7	9.4	6.7
NDYS-141-3	113.0	89	156	23.3	3.6	2.4	91.5	13.8	8.5
YSWB-2009	104.0	88	98	21.1	2.6	4.5	88.3	13.1	6.8
NDYS-107-1	109.0	106	76	31.6	3.1	2.6	74.7	8.1	5.8
YSK-09-1	109.0	89	79	41.0	5.4	6.6	78.8	10.6	6.3
NRCYS-05-03	106.0	98	106	40.4	4.5	7.2	50.6	6.7	7.3
Mean of <i>yellow sarson</i>	110.1	97	92	31.8	4.1	5.0	81.5	10.8	7.2
DRMREJ-902	103.5	130	167	15.0	4.1	5.2	155.8	9.4	6.7
DRMREJ-903	96.0	119	107	13.3	4.1	3.2	108.3	4.4	4.5
NDRE-7	117.0	119	99	14.6	3.8	7.1	47.5	13.5	7.9
JD-6	120.5	110	126	19.0	4.2	5.7	92.3	6.0	4.6

NML-100	118.5	99	89	16.0	3.9	7.9	134.0	11.9	7.5
MPJ-135	116.0	128	178	18.3	3.4	5.4	87.5	15.0	7.9
NRCHB-101	122.5	152	178	22.0	4.7	5.5	74.5	14.5	9.6
Mean of mustard	113.4	122	135	18.3	4.0	5.7	100.0	10.7	7.0
Overall Mean	105.8	101	93	24.9	4.0	5.3	78.7	10.8	7.5
SEm±	0.9	5.5	6.8	1.7	0.1	0.1	2.7	1.6	0.5
CD 5%	2.5	15.9	19.5	5.0	0.1	0.4	7.7	4.5	1.4

Where; DM: days to maturity, PH: plant height, SQP: number of siliquae per plant, SSQ: number of seeds per siliquae, TSW: thousand seed weight, NRA: nitrogen reductase activity, NUE: nitrogen-use efficiency, SYH: seed yield per ha

Genetic parameters

The genetic parameters are presented in Table 3. The highest genotypic coefficient of variation (GCV, 39.7%) and phenotypic coefficient of variation (PCV, 41.1%) were observed for siliquae per plant followed by nitrate reductase activity, seeds per siliqua, NUE and leaf N. For obvious reason, PCV was higher than GCV for all the traits but the difference between them was narrow implying that genotypes contributed more than environment in the expression of these traits. Hence selection based on phenotype would be effective. Only GCV does not provide the information regarding the genetic gain that could be achieved through selection on the basis of phenotypic traits unless the heritable portion of phenotype was known (Burton, 1952). Again, to estimate the selection effects, heritability accompanied with genetic advance is more useful than heritability alone (Johnson and Hanson, 2003). Estimation of heritability (broad sense) and genetic advance was therefore important. High heritability was observed for leaf N (98.6%), 1000-seed weight (98.5%), NRA (98.4%), days to maturity (98.3%), siliquae per plant (93.6%) and seeds per siliqua (93.0%). Moderate

heritability was observed for NUE (62.5%). High genetic advance was observed for siliquae per plant (79.1%), NRA (77.4%), seeds per siliqua (71.3%), leaf N (60.7%), NUE (43%) and plant height (28.0%). Moderate (18.4%) genetic advance was observed for days to maturity. The high broad sense heritability coupled with high genetic advance indicates additive genetic effects that govern the trait; hence these traits could be directly selected for crop improvement. In the present study, high heritability and high genetic advance were recorded for all traits under study except days to maturity for which genetic advance was moderate and NUE that showed moderate heritability. Singh *et al.* (2022) reported high degree of PCV and GCV for primary branches per plant, 1000-seed weight, seeds per siliqua and seed yield per plant. They also reported high heritability and high genetic advance for the 13 traits they studied in Indian mustard and emphasized the importance of studying these components for crop improvement programme through selection of parents with desirable traits. Similarly, Borpatra Gohain *et al.* (2020) reported high heritability and high genetic advance for NRA and NUE in rapeseed.

Table 3: Genetic parameters for yield attributes and nitrogen-use efficiency

Character	Genotypic coefficient of variation (%)	Phenotypic coefficient of variation (%)	Heritability (bs) (%)	Genetic advance (%)
Days to maturity	9.0	9.1	98.3	18.4
Plant height (cm)	15.3	17.2	79.3	28.0
Siliquae per plant	39.7	41.1	93.6	79.1
Seeds per siliqua	35.9	37.2	93.0	71.3
1000-seed weight (g)	14.7	14.8	98.5	30.1
Leaf N%	29.7	29.9	98.6	60.7
NRA ($\mu\text{mol NO}_2/\text{g FW/hr}$)	37.9	38.2	98.4	77.4
NUE (kg/kg)	26.4	33.4	62.5	43.0
Seed yield (q/ha)	17.1	19.4	77.8	31.1

Genotypic correlations

Seed yield had a strong positive correlation (Table 4) with NUE ($r = 0.76$) at genotypic level, indicating the

significance of enhanced NUE for seed yield improvement. Siliquae per plant was positively correlated with days to maturity ($r=0.69$), plant height

($r=0.62$) and nitrate reductase activity ($r=0.55$). There was also positive relation of days to maturity with plant height ($r=0.44$) and NRA ($r=0.42$). Similar findings were reported by Swetha *et al.* (2019) and Singh *et al.* (2013). They reported positive correlation of seed yield with plant height, siliquae on main shoot and thousand

seed weight. Pandey *et al.* (2020), Tiwari *et al.* (2017) and Kumar *et al.* (2018) reported positive correlation of seed yield with number of seeds per siliqua in Indian mustard. In the same way Borpatra Gohain *et al.* (2020) reported positive genetic correlation between seed yield and NUE in rapeseed.

Table 4: Genotypic correlation coefficients between yield attributes

Character	PH	SQP	SSQ	TSW	LN%	NRA	NUE	SYH
DM	0.44*0.	69**	0.01	0.35	0.01	0.42*	-0.22	-0.34
PH		0.62**	-0.06	0.33	0.14	0.10	-0.23	-0.20
SQP			-0.06	0.23	-0.08	0.55**	0.24	0.19
SSQ				0.44*	-0.22	-0.15	0.01	0.01
TSW					0.15	0.09	-0.33	-0.13
LN%						0.11	-0.01	-0.01
NRA							0.14	-0.02
NUE								0.76**

* Significant at 5% level of probability; ** significant at 1% level of probability; DM: days to maturity, PH: plant height, SQP: siliquae/plant, SSQ: seeds/siliqua, TSW: 1000 seed weight, LN%: leafN%, NRA: nitrate reductase activity, SYH: seed yield per ha

Acknowledgement

The authors are grateful to the authority of Assam Agricultural University, Jorhat for providing the facilities for the study.

References

- Anonymous. 2022. Agricultural Statistics at a Glance, 2022. Government of India, Ministry of Agriculture & Farmers Welfare, Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Economics and Statistics. www.agricoop.nic.in
- Borpatra Gohain P, Gogoi S, Das K and Barua PK. 2020. Combining ability for nitrogen use efficiency in a diallel cross of Indian rapeseed (*B. rapa*). *Int J Curr Microbiol App Sci* **9**: 1746-1760.
- Burton GW. 1952. Quantitative inheritance in grasses. Proceedings of 6th International Grassland Congress. **1**: 227-283.
- Choudhary RL, Jat RS, Singh HV, Dotaniya ML, Meena MK, Meena VD and Rai PK. 2023. Effect of superabsorbent polymer and plant bio-regulators on growth, yield and water productivity of Indian mustard (*B. juncea*) under different soil moisture regimes. *J Oilseed Brassica* **14**: 11–19.
- Fageria NK and Baligar VC. 2005. Enhancing nitrogen use efficiency in crop plants. *Adv Agron* **88**: 97-158.
- Gan Y, Malhi SS, Brandt S, Katempa-Mupondwa F and Stevenson C. 2008. Nitrogen use efficiency and nitrogen uptake of *juncea* canola under diverse environments. *Agron J* **100**: 285-295.

- Jat RS, Singh VV, Sharma P and Rai PK. 2019. Oilseed brassica in India: demand, supply, policy perspective and future potential. *OCL* **26**: 1-8.
- Jat RS and Choudhury M. 2019. Nitrogen utilization efficiency variability in genotypes of Indian mustard (*B. juncea*) under contrasting N supply. *J Plant Nutr* **42**: 1-12.
- Johnson BL and Hanson BK. 2003. Row spacing interaction on spring canola performance in the Northern great plains. *Agron J* **95**: 703-708.
- Kumar A, Singh M, Yadav RK, Singh P and Lallu. 2018. Study of correlation and path coefficient among the characters of Indian mustard. *Pharm Innov J* **7**: 412-416.
- Mahmuti M, West JS, Watts J, Gladders P and Fitt BDL. 2009. Controlling crop disease contributes to both food security and climate change mitigation. *Int J Agric Sustain* **7**: 189-202.
- Pandey SK, Srivastava KK, Negi S, Khan NA and Singh RK. 2020. Variability, trait relationship and path analysis for seed yield and seed quality parameters in Indian mustard (*B. juncea*). *J Oilseed Brassica* **11**: 69-76.
- Schjoerring JK, Bock JGH, Gammelvind L, Jensen CR and Mogensen VO. 1995. Nitrogen incorporation and remobilization in different shoot components of field-grown winter oilseed rape (*B. napus*) as affected by rate of nitrogen application and irrigation. *Plant Soil* **177**: 255–264.
- Singh A, Avtar R, Singh D, Sangwan O, Thakral NK, Malik VS, Goyat B and Dalal U. 2013. Combining

- ability analysis for seed yield and component traits in Indian mustard (*B. juncea*). *Res Plant Biol* **3**: 26-31.
- Singh S, Kumar V, Singh SK and Daneva V. 2022. Genetic variability, interrelation and path analysis for yield and yield characters in Indian mustard (*B. juncea*). *J Oilseed Brassica* **13**: 112-118.
- Srivastava HS and Ormrod DP. 1984. Effects of nitrogen dioxide and nitrate nutrition on growth and nitrate assimilation in bean leaves. *Plant Physiol* **76**: 418-423.
- Swetha M, Janeja HS, Singh H, Sravani M, Rajaneesh K and Madakemohekar AH. 2019. Genetic evaluation of Indian mustard (*B. juncea*) genotypes for yield and quality parameters. *Plant Arch* **19**: 413-417.
- Tiwari AK, Singh SK, Tomar A and Singh M. 2017. Heritability, genetic advance and correlation coefficient analysis in Indian mustard (*B. juncea*). *J Pharmacogn Phytochem* **6**: 356-359.
- USDA. 2023. World Agricultural Production, Foreign Agricultural Service/ United States Department of Agriculture, pp. 34.