*Indian Journal of Agronomy* **55** (4): 264–269 (December 2010)

# Productivity and response of quality brassicas (*Brassica* sp.) – cowpea (*Vigna unguiculata)* sequence under different sources of nutrients and sulphur levels

**N.T.Q. THUAN AND D.S. RANA***

*Division of Agronomy, Indian Agricultural Research Institute, New Delhi 110 012*

Received: August, 2009

## ABSTRACT

Information on comparative response of quality and traditional rapeseed-mustard genotypes to inorganic and organic source of nutrients are meager. Besides, organic mustard oil is becoming popular in the market. Hence, present experiment was conducted in a fixed plot field at New Delhi between 2005–2007. Two genotypes of Indian mustard {*Brassica juncea* (L.) Czernj & Cosson} *viz.,* 'Pusa Mahak' {high erucic acid (EA) and glucosinolate content (GC)}, and 'Pusa Karishma' low in EA and high GC and one genotype of summer rape (*Brassica napus* L.) *viz.,* 'GSC 3A' (low in EA and GC) were evaluated under organic and inorganic sources of nutrients and sulphur (S) levels and residual effect of treatments were examined on succeeding cowpea [*Vigna unguiculata* (L.) Walp.] for green pods. 'Pusa Mahak' recorded greater number of siliquae/plant and test weight, while number of seeds/siliqua were found maximum in 'GSC-3A' 'Pusa Mahak' (2.08 t/ha) and 'Pusa Karishma' (1.91 t/ha) being on par produced significantly higher seed yield than 'GSC-3A' (1.45 t/ha). In first year, seed yield (2.13 t/ha) recorded was maximum owing to integrated use of nutrients, while in the second crop cycle, integrated and organic source of nutrients, recorded similar seed yield (2.30 and 2.23 t/ha), but both the treatments were markedly superior when compared with fertilizers. Application of sulphur @ 40 kg/ha produced 19.3% higher seed yield than control. Residual effect of integrated nutrient management (INM) and organic nutrition on green pod yield of cowpea was found significant over fertilizers. System productivity as mustard seed equivalent was recorded maximum with 'Pusa Mahak'-cowpea system, INM in the first crop cycle and organic use in the second crop cycle and 40 kg S/ha. Significant interaction was recorded between the genotypes and S levels. S uptake in seed and unit response to S application (kg seed/kg S) was highest in 'Pusa Mahak' (10.4).

***Key words**: Brassicas*, Cowpea, Nutrient source, Productivity, Sulphur

Traditional varieties of rapeseed-mustard (*Brassica* sp) contain > 40-60% long chain erucic acid (EA) in oil, consumption of which has been reported to cause mycocardinal lesions and fat deposition. Similarly, seed meal contains high glucosinolates content (GC), which produces toxic products on consumption, leading to inhibition of the thyroid function, goiter and reduced palatability. Efforts made in Canada and other countries including India since 1960 resulted in developing varieties of *Brassica napus, B. juncea* and *B. rapa*, having < 2% EA oil and <30 micro-moles of GC/gram of oil free seed meal and genotypes having these qualities are called as 'canola'. Canola varieties developed in India using exotic germplasm, are likely to respond/perform differently to the growing environment. Rana and Pachauri (2001), and Thakur *et al.* (2005) reported marked variation in the morphological characters, quality parameters and nutrients requirement between quality and traditional genotypes. Information on comparative response of quality and traditional rapeseed-mustard genotypes to inorganic, organic and integrated nutrient management (INM) are not available. Besides, organic mustard oil is becoming popular in the market, so there is a need to work out the productivity and economics of mustard grown under different sources of nutrients. Walia and Kler (2008) found organic and INM are more productive than fertilizers in soybean-wheat sequence. Sulphur is yet another major nutrient for rapeseed-mustard group of crops. Optimum rate of S depends upon the soil S status, yield potential and quality traits of genotypes. Traditional genotypes of *Brassica* sp. showed differential response to S levels due to variation in yield potential and life-cycle. The quality genotypes may differ in their requirement for sulphur in contrast to traditional genotypes. Rana and Giri (2006) reported significant interaction between brassica genotypes and sulphur levels. All the varieties under test responded to S application, but response was less in canola type. The genotypes, nutrient sources and S levels are likely to have residual effect on

***Corresponding author** (E mail:dsrana5554@yahoo.com)

succeeding crops and there is need to evaluate the same. The present investigation was undertaken to bridge the above information gaps.

## MATERIALS AND METHODS

A fixed plot field experiment was conducted at New Delhi during winter and summer of 2005-06 and 2006-07. The soil of experimental site is sandy loam in texture and contained 0.38% organic carbon, 182, 13.4, 220 and 12.2 kg N-P-K-S/ha in 0-30 cm soil layer. Initial pH and electrical conductivity (dS/m) was 7.73 and 0.41, respectively. Treatments comprises of three genotypes of *oleiferous brassicas viz*., 'Pusa Mahak' {non-canola, having high erucic acid (EA) and glucosinolate content (GC)} and 'Pusa Karishma' (semi-canola, having low EA and high GC) of Indian mustard, [(*Brassica juncea* (L.) Czernj & Cosson] and 'GSC 3A' (Canola, having low EA and GC) of summer rape (*Brassica napus*), four levels and sources of nutrients *viz*., control, recommended dose of fertilizers i.e. RDF 80-17.4-33.3 kg N-P-K/ha, recommended dose of nitrogen (RDN) through FYM and 50% RDF through inorganic + 50% RDN through FYM and two levels of sulphur *viz*., control and 40 kg/ha. A fixed plot field experiment was carried out in three times replicated split-split plot design. Main plots of the design received three genotypes of *brassicas*, while sub-plots and sub-sub plots received four levels of nutrient sources and two levels of sulphur, respectively.

The FYM used in experiment contained 0.53-0.15-0.40% N-P-K in 2005 and 0.48-0.18-0.40% N-P-K in 2006. Calculated dose of FYM (15.1 in 2005 and 16.6 t/ha in 2006) as per treatments was applied 20 days before sowing of the crop during both the crop seasons. Phosphorus and potassium as per treatment was given through diammonium phosphate (48% $P_2O_5$ and 18% (N) and muriate of potash (60% $K_2O$), respectively. Remaining N as per treatment was added through urea. Sulphur as per treatments was applied through gypsum (Agricultural grade containing 18% S). Genotypes of mustard were sown on 28 October and 18 October during 2005 and 2006, respectively, using 4 kg seed/ha. Harvesting of 'Pusa Mahak', 'Pusa Karishma' and 'GSC 3A' was done on 16, 25 and 20 March 2006 and 10, 18 and 15 March 2007, respectively. Beside pre-sowing irrigation, crop received two irrigations during both the crop seasons. For controlling weeds, pre-emergence application of pendimethalin @ 1 kg a.i./ha followed by hand weeding at 20 days after sowing (DAS) was done. All the genotypes were sown at 45 cm row-to-spacing and thinning was done at 15 DAS. to maintain intra-row spacing of 10 to 12 cm. After the harvest of rapeseed-mustard, irrigated cowpea 'Pusa Komal' was sown on 11 April 2006 and 5 April 2007 at inter-row spacing of 45 cm using seed rate of 50 kg/ha. Cowpea green pods were harvested through four pickings. Beside pre-sowing irrigation, crop received four irrigations and also pre-monsoon shower till last picking on 12 July and 6 July 2006 and 2007, respectively. After the last picking, residue of the first crop of cowpea was incorporated in the soil and land was kept fallow till sowing of second year crop of mustard. Cowpea crop was grown on residual fertility without disturbing the layout over two crop seasons. Both the crops of the system were grown following recommended cultivation practices except the variation in treatments.

Total productivity of the system in mustard seed equivalent yield was calculated on the basis of support price for the main produce during 2007 and prevailing market prices for the inputs. Sulphur content was determined by turbidimetric method. The uptake of sulphur in each component was calculated by multiplying the sulphur content (%) and dry matter yield of various components of crop under different treatments. Values of uptake so obtained were pooled to work out the total removal from the soil. The data were subjected to analysis of variance by following standard statistical procedure.

## RESULTS AND DISCUSSION

### *Yield attributes and yield of quality brassica genotypes*

Number of siliquae/plant, number of seeds/siliqua, length of siliqua and test weight of *brassica* genotypes as influenced by nutrient sources and sulphur levels is presented in Table 1. Across the seasons, 'Pusa Mahak' and 'Pusa Karishma' recorded similar number of siliquae/plant, number of seeds/siliqua and length of siliqua, except test weight, where 'Pusa Mahak' was superior to 'Pusa Karishma'. 'GSC 3A' produced significantly higher number of seeds/siliqua and length of siliqua, when compared with 'Pusa Karishma' and 'Pusa Mahak'. On an average, 'GSC 3A' produced 58% more seeds/siliqua than 'Pusa Mahak' and 'Pusa Karishma'. 'GSC 3A' recorded marked decrease in number of siliquae/plant and test weight compared to 'Pusa Mahak' and 'Pusa Karishma'. These variations in yield attributes of brassica genotypes may be attributed to inherent variation and changes in genetic composition for quality improvement. Siliqua length of 'GSC 3A' might be probable reason for higher number of seeds/siliqua. 'Pusa Mahak' recorded significantly greater test weight than 'Pusa Karishma' though they belong to same species. Test weight had a reverse relation to the quality improvement in *Brassica juncea*, so with zero erucic acid character, test weight declined markedly in 'Pusa Karishma'. Due to variation in yield attributes, seed yield of genotypes recorded marked variation (Table 1). 'Pusa Mahak' and 'Pusa Karishma' recorded similar seed yield during both the seasons, but both genotypes recorded significant improvement over 'GSC 3A'. 'Pusa Mahak' recorded 6.22 and 33.2% increase in seed yield over 'Pusa Karishma' and 'GSC 3A' during 2005-06 and 5.0 and 53.7% during 2006-07, respectively. Seed yield of 'Pusa Mahak' invariably was higher than 'Pusa Karishma' because of its greater test weight, and compact plant biotype. Lowest seed yield of 'GSC 3A' was attributed to its lowest plant height, dry matter accumulation/plant, number of siliquae/plant and test weight, which could not be compensated by the effect of more number of seeds/siliqua and siliqua length. Similar variations in the yield attributes and seed yield of *brassicas* genotypes were also reported by Rana and Pachauri (2001), Rana (2002), Thakur *et al.* (2005) and Rana and Giri (2006).

Control recorded marked decline in seed yield and yield attributes compared to nutrient application. INM produced significantly the highest number of siliquae/plant, number of seeds/siliqua, length of siliqua and seed yield followed by fertilizers nutrition during first crop cycle. Test weight remained unaffected due to nutrient sources. In the second season FYM alone and INM being on par recorded significantly higher yield attributes and seed yield over fertilizers nutrition except number of seeds/siliqua. The INM recorded 5.6 and 24.2% increase in seed yield over fertilizers and FYM alone during 2005-06 and 17.2 and 3.2% during 2006-07, respectively. In the first crop cycle, superiority of INM over fertilizers and FYM use may be attributed to balanced fertilization of crop along with micronutrients through the application of 8 t FYM/ha. Performance of inorganic sources of nutrients was better than FYM alone in the first year due to interlocking of nutrients especially N and slow mineralization of FYM. Experiment was conducted on fixed plot, so in the second crop cycle, there was improvement in the soil productivity in the plots which received 31.69 t FYM (15.09 in the first year + 16.60 t in the second year). Besides this, for the second crop of rapeseed-mustard, there was sufficient build up of N due to cowpea cultivation, recycling of cowpea stover and keeping the field fallow for 3 months before sowing the second crop. This improvement in soil fertility, resulted in better performance of rapeseed–mustard under organic than inorganic use of nutrients. Panwar (2008), Bodake and Rana (2009) also reported INM more productive than inorganic use of nutrients in the first crop cycles and organic alone and INM than fertilizers alone in the subsequent crop cycles.

**Table 1.** Yield attributes, mustard seed yield, cowpea green pod yield and system productivity of *brassicas*-cowpea cropping system as influenced by direct and residual effect of nutrient sources and sulphur levels (mean of 2 years)

| Treatment | Siliquae/plant | | Seeds/siliqua | | Length/siliqua (cm) | | Test weight (g) | | Mustard seed yield (t/ha) | | Cowpea green pod yield (t/ha) | | Mustard seed equivalent of system (t/ha) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2005-06 | 2006-07 | 2005-06 | 2006-07 | 2005-06 | 2006-07 | 2005-06 | 2006-07 | 2005-06 | 2006-07 | 2005-06 | 2006-07 | 2005-06 | 2006-07 |
| *Genotype* | | | | | | | | | | | | | | |
| 'Pusa Mahak' | 301 | 360 | 13.7 | 14.6 | 4.7 | 4.9 | 4.90 | 5.20 | 1.91 | 2.24 | 10.05 | 9.31 | 4.96 | 4.95 |
| 'Pusa Karishma' | 308 | 366 | 13.2 | 14.8 | 4.8 | 4.9 | 4.30 | 4.20 | 1.80 | 2.13 | 10.43 | 9.52 | 4.86 | 4.90 |
| 'GSC 3A' | 253 | 304 | 21.5 | 22.7 | 6.5 | 6.6 | 3.60 | 3.60 | 1.44 | 1.45 | 11.23 | 10.31 | 4.54 | 4.46 |
| SEm ± | 3 | 3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.03 | 0.07 | 0.03 | 0.03 | 0.24 | 0.26 | 0.06 | 0.08 |
| CD (P=0.05) | 11 | 14 | 0.9 | 0.5 | 0.2 | 0.3 | 0.14 | 0.28 | 0.13 | 0.12 | 0.94 | NS | 0.25 | 0.32 |
| *Nutrient source* | | | | | | | | | | | | | | |
| Control | 193 | 226 | 15.2 | 16.4 | 5.0 | 5.2 | 4.00 | 4.00 | 1.13 | 1.27 | 7.07 | 6.19 | 3.17 | 3.05 |
| RD of NPK through fertilizers | 337 | 349 | 16.3 | 17.5 | 5.4 | 5.4 | 4.30 | 4.30 | 1.93 | 1.96 | 10.26 | 9.21 | 4.90 | 4.65 |
| RD of N through FYM | 263 | 393 | 16.1 | 17.7 | 5.2 | 5.6 | 4.40 | 4.50 | 1.68 | 2.23 | 12.42 | 12.07 | 5.29 | 5.73 |
| ½ RD NPK + ½ RDN-FYM | 358 | 406 | 16.9 | 17.8 | 5.6 | 5.7 | 4.40 | 4.50 | 2.13 | 2.30 | 12.53 | 11.39 | 5.78 | 5.59 |
| SEm ± | 6 | 4 | 0.1 | 0.1 | 0.04 | 0.04 | 0.05 | 0.04 | 0.05 | 0.05 | 0.19 | 0.22 | 0.07 | 0.08 |
| CD (P=0.05) | 19 | 13 | 0.4 | 0.4 | 0.11 | 0.12 | 0.16 | 0.12 | 0.15 | 0.15 | 0.57 | 0.65 | 0.20 | 0.23 |
| *Sulphur level (kg/ha)* | | | | | | | | | | | | | | |
| 0 | 280 | 339 | 15.9 | 17.2 | 5.3 | 5.4 | 4.10 | 4.20 | 1.57 | 1.76 | 10.19 | 9.33 | 4.56 | 4.55 |
| 40 | 295 | 348 | 16.3 | 17.5 | 5.4 | 5.5 | 4.40 | 4.50 | 1.86 | 2.12 | 10.94 | 10.11 | 5.00 | 4.98 |
| SEm ± | 3 | 2 | 0.1 | 0.1 | 0.04 | 0.04 | 0.05 | 0.03 | 0.02 | 0.02 | 0.13 | 0.11 | 0.04 | 0.04 |
| CD (P=0.05) | 12 | 6 | NS | NS | NS | NS | 0.14 | NS | 0.06 | 0.05 | 0.37 | 0.32 | 0.13 | 0.11 |

Number of siliquae/plant and test weight were found to increase markedly due to S application over control. The sulphur application on an average induced 19.3% increase in seed yield over control. This could be ascribed to the role of S as constituent of protein, coenzyme A, glutathione, vitamins and oils; synthesis of protein and oil, energy transfer similar to P and activation of enzymes. Oleiferous brassicas also required sulphur in specific ratio with nitrogen to ensure maximum production of dry matter and protein. Besides this, N and S were reported to promote uptake of each other to maintain ionic balance. Misra (2003) reported 27.6% increase in seed yield due to 40 kg S application/ha. Application of 30 kg S/ha caused was also found to increase grain yield of pigeonpea by 38% (Palsaniya and Ahlawat, 2009). Similar results were reported by Rana and Giri (2006).

*Residual effect on green pod yield of cowpea*

Residual effect of treatments given to brassicas was found significant on the green pod yield of cowpea (Table 1). Cowpea after 'GSC 3A' recorded the highest green pod yield during both the seasons, but the differences among the genotypes were found significant only between 'GSC 3A'-cowpea and 'Pusa Mahak'-cowpea system during 2006. In 2006, the green pods yield owing to residual effect of INM was found on par with FYM aone, but both the treatments recorded marked improvement in green pod yield overs residual effect of fertilizers alone and control. Green pod yield due to residual effect of INM was found 0.9 and 22.1% higher than FYM alone and fertilizers alone in 2006. In 2007, green pod yield of cowpea due to residual effect of FYM alone was significantly higher than the residual effect of INM and fertilizers alone. Green pod yield due to residual effect of organic was 6.0, 31.1% higher than INM and fertilizers. Residual effect of FYM alone and INM on the succeeding crop may be attributed to the effect of steady availability of nutrients for longer period from the organic sources than inorganic sources. Besides, primary nutrients, organic sources contribute sizeable quantity of secondary and micronutrients also and found to improve the physico-chemical properties of soil, which had favourable effects on crop growth and development. Similar residual effects of organic, INM and inorganic sources of nutrients were reported by Panwar (2008) and Bodake and Rana (2009). Residual effect of S was found perceptible on the green pod yields of cowpea during both the seasons, which could be ascribed to under-utilization of S applied to brassicas. Palsaniya and Ahlawat (2009) also reported residual effect of S applied to pigeonpea on the succeeding crop of wheat. Rana *et al.* (2007) also reported residual effect of S applied to mustard on sunflower and S applied to sunflower on succeeding blackgram in mustard-sunflower-blackgram crop sequence.

*System productivity*

System productivity in mustard seed equivalent was marginally higher in the first year than the second year (Table 1). In the first year, all the systems recorded similar system productivity. In the second crop cycle, 'Pusa Mahak'-cowpea system recorded the highest system productivity, statistically similar to 'Pusa Karishma'-cowpea, but productivity of both the systems was markedly higher than the 'GSC 3A'-cowpea system. 'GSC 3A'-cowpea produced 8.4 and 6.6% less system productivity than 'Pusa Mahak'-cowpea and 'Pusa Karishma'-cowpea system during 2005-06 and corresponding figures for 2006-07 were 9.9 and 9.0%, respectively. INM recorded significantly the highest system productivity during 2005-06, which was 9.2 and 18.0% higher than FYM alone and fertilizers alone, respectively. In 2006-07, FYM alone produced the highest system productivity, which was 2.4 and 23.3% higher than INM and fertilizers alone, respectively. S application caused conspicuous increase in system productivity over control and this increase was 9.7 and 9.5% between 2005-06 and 2006-07, respectively. This behavior of system productivity is traced to the effect of treatments on the economic yield of component crops of the system. Direct and residual effect of FYM alone became more pronounced on the system productivity during the second crop-cycle due to improvement in soil health. Application of organic amendmants ensure long-term sustainability of soil fertility by improving levels of soil organic carbon, availability of nutrients and soil microbial activities (Malero *et al.,* 2007 and Bodake and Rana, 2009). These findings are in agreement with Palsaniya and Ahlawat (2009).

*S uptake*

'Pusa Mahak' and 'Pusa Karishma' being on par in total S uptake, had significant edge over 'GSC 3A' (Table 2). 'Pusa Karishma' removed 42.4 and 38.1% higher S than 'GSC 3A' during 2005-06 and 2006-07, respectively. In seed, 'Pusa Mahak' removed significantly higher S than 'Pusa Karishma' and 'GSC 3A', except S uptake in seed during 2006-07. The S uptake in stover and leaf was significantly the highest in 'Pusa Karishma', while with respect of S uptake in roots 'GSC 3A' showed its superiority over other genotypes. In 2005-06, INM removed significantly the greater amount of S in different plant parts and total S, followed by fertilizers alone. In the second year also INM maintained its superiority with respect to total S uptake in different plant parts followed by FYM use. Total S removal due to INM was found 35.4 and 4.9

**Table 2.** Sulphur content and S uptake (kg/ha) in different plant parts and total uptake by *brassicas* genotypes at harvest as affected by nutrient sources and sulphur levels

| Treatment | Sulphur uptake (kg/ha) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2005-06 | | | | | 2006-07 | | | | |
| | Seed | Stover | Root | Leaf | Total | Seed | Stover | Root | Leaf | Total |
| *Genotype* | | | | | | | | | | |
| 'Pusa Mahak' (JD 6) | 10.07 | 16.60 | 0.23 | 1.75 | 28.65 | 11.37 | 19.93 | 0.29 | 2.37 | 33.95 |
| 'Pusa Karishma' | 9.17 | 18.35 | 0.20 | 2.00 | 29.71 | 11.09 | 21.04 | 0.25 | 2.48 | 34.85 |
| 'GSC 3A' | 5.37 | 13.72 | 0.24 | 1.54 | 20.87 | 6.59 | 16.39 | 0.29 | 1.97 | 25.23 |
| SEm ± | 0.11 | 0.15 | 0.004 | 0.05 | 0.32 | 0.09 | 0.140 | 0.004 | 0.02 | 0.34 |
| CD (P=0.05) | 0.42 | 0.56 | 0.015 | 0.20 | 1.21 | 0.35 | 0.550 | 0.015 | 0.06 | 1.30 |
| *Nutrient source* | | | | | | | | | | |
| Control | 5.58 | 10.71 | 0.17 | 1.22 | 17.68 | 5.40 | 9.59 | 0.17 | 1.30 | 16.45 |
| RDF | 9.63 | 19.33 | 0.23 | 1.98 | 31.16 | 9.66 | 20.64 | 0.26 | 2.34 | 32.90 |
| RD N through FYM | 7.37 | 14.88 | 0.23 | 1.66 | 24.13 | 11.48 | 22.68 | 0.32 | 2.62 | 37.10 |
| ½ RD NPK + ½ RDN-FYM | 10.24 | 19.98 | 0.26 | 2.20 | 32.68 | 12.19 | 23.56 | 0.35 | 2.83 | 38.94 |
| SEm ± | 0.13 | 0.19 | 0.006 | 0.05 | 0.24 | 0.10 | 0.20 | 0.006 | 0.01 | 0.21 |
| CD (P=0.05) | 0.39 | 0.57 | 0.018 | 0.15 | 0.71 | 0.30 | 0.61 | 0.019 | 0.04 | 0.60 |
| *Sulphur level* (kg/ha) | | | | | | | | | | |
| 0 | 7.37 | 13.72 | 0.19 | 1.58 | 22.86 | 8.63 | 16.42 | 0.22 | 2.08 | 27.35 |
| 40 | 9.03 | 18.73 | 0.26 | 1.95 | 29.97 | 10.73 | 21.82 | 0.33 | 2.46 | 35.34 |
| SEm ± | 0.10 | 0.13 | 0.006 | 0.04 | 0.17 | 0.09 | 0.12 | 0.005 | 0.01 | 0.30 |
| CD (P=0.05) | 0.29 | 0.37 | 0.019 | 0.12 | 0.51 | 0.25 | 0.35 | 0.014 | 0.03 | 0.89 |

higher than FYM and fertilizer alone during 2005-06 and 5.0 and 18.4% higher during 2006-07, respectively. Total S uptake and uptake in different plant parts was markedly higher due to S application than no S. Total S uptake under 40 kg S/ha recorded 31.1 and 29.2% increase over control during 2005-06 and 2006-07, respectively. Rana (2002), Misra (2003) and Palsaniya and Ahlawat (2009) also recorded marked increase in S uptake due to S application.

### *Interaction between brassicas genotypes and sulphur*

Brassica genotypes originated in different climatic conditions and therefore have different habit and thermo-photo-periodic adaptavity and thus different sensitivity to inputs. Interactive effects of genotypes and S levels were found significant on seed yield (Table 3). Due to sulphur application the genotypes recorded marked improvement in seed yield, but the increase in seed yield was more in 'Pusa Mahak'. 'Pusa Mahak', 'Pusa Karishma' and 'GSC 3A' recorded 22.1, 18.2 and 15.2% increase in seed yield due to S application in 2005-06 and 23.1, 20.0 and 18.4% during 2006-07, respectively (Table 4). Pusa Mahak recorded 9.25 kg and 11.6 kg seed yield per kg of S used in the respective season followed by 'Pusa Karishma' (7.5 and 9.7 kg seed/kg S) and lowest was recorded in 'GSC 3A' (5.2 and 6.1 kg seed/kg S) (Table 4). This differential response of genotypes to per kg S application may be attributed to the yield potential of each genotype and changes in their quality parameters, which changed their requirement to S and other agronomical inputs. Similar variable response of rapeseed-mustard genotypes to S application was also reported by Rana (2002), Thakur *et al.* (2005) and Rana and Giri (2006).

Interaction effect between the brassica genotypes and S levels on the S content in seed and stover and on total S uptake was noticed during both the crop cycles (Table 4). 'Pusa Mahak' recorded significantly the greater S content in seed under control during both the crop cycles. At 40 kg S, 'Pusa Mahak' and 'Pusa Karishma' had similar S content in seed but it was markedly higher than 'GSC 3A'.

**Table 3.** Interaction effect of quality *brassicas* genotypes and sulphur levels on seed yield (kg/ha) 2005-06

| Treatment | 0 kg S | 40 kg S/ha | Mean increase in seed yield (kg seed/kg S) |
|---|---|---|---|
| 'Pusa Mahak' | 1,723 | 2,104 | 9.25 |
| 'Pusa Karishma' | 1,652 | 1,952 | 7.50 |
| 'GSC 3A' | 1,333 | 1,540 | 5.17 |
| SEm ± | | 31 | |
| CD (P=0.05) | | 92 | |
| | | *2006-07* | |
| 'Pusa Mahak' | 2,004 | 2,468 | 11.60 |
| 'Pusa Karishma' | 1,935 | 2,323 | 9.70 |
| 'GSC 3A' | 1,382 | 1,578 | 6.15 |
| SEm ± | | 26 | |
| CD (P=0.05) | | 76 | |

**Table 4.** Interaction effects of quality *brassicas* genotypes and sulphur levels on S content (%) in seed and stover and total S uptake

| Treatment | S content in seed | | S content in stover | | Total S uptake (kg/ha) | |
|---|---|---|---|---|---|---|
| | 0 kg S | 40 kg S | 0 kg S | 40 kg S | 0 kg S | 40 kg S/ha |
| | 2005-06 | | 2005-06 | | 2005-06 | |
| 'Pusa Mahak' | 0.46 | 0.51 | 0.22 | 0.28 | 23.9 | 35.4 |
| 'Pusa Karishma' | 0.40 | 0.49 | 0.21 | 0.30 | 24.6 | 34.8 |
| 'GSC 3A' | 0.31 | 0.35 | 0.26 | 0.30 | 19.0 | 22.7 |
| SEm ± | 0.005 | | 0.004 | | 0.90 | |
| CD (P=0.05) | 0.015 | | 0.012 | | 2.60 | |
| | 2006-07 | | 2006-07 | | 2006-07 | |
| 'Pusa Mahak' | 0.42 | 0.49 | 0.22 | 0.31 | 28.9 | 39.1 |
| 'Pusa Karishma' | 0.39 | 0.48 | 0.23 | 0.31 | 30.1 | 39.6 |
| 'GSC 3A' | 0.31 | 0.37 | 0.27 | 0.31 | 23.1 | 27.4 |
| SEm ± | 0.006 | | 0.005 | | 0.80 | |
| CD (P=0.05) | 0.017 | | 0.014 | | 2.31 | |

Under control, 'GSC 3A', recorded significantly greater S content in stover, while at 40 kg S, 'GSC 3A' and 'Pusa Karishma' being on par recorded greater S content in stover than Pusa Mahak during 2005-06. In 2006-07, no variations in S content among the genotypes were recorded at 40 kg S/ha. At different levels of S, genotypes showed marked variation in total S uptake and between the levels proportionate increase in S uptake among the genotypes also showed marked variations (Table 5). S is mobile in the plant system and it moves from older to younger plant parts in response to demand. So its variable distribution in different plant parts and variation among the genotypes, may be attributed to its mobile nature and variation in demand/requirement among the plant parts and genotypes due to genetic variation. Rana (2002), Rana and Giri (2006) and Palsaniya and Ahlawat (2009) also reported significant interaction of genotypes with nitrogen and sulphur levels with respect to seed yield, nutrients content and uptake.

It may be concluded that non-quality brassicas had edge over quality brassicas in terms of seed yield and S use efficiency. In the brassica-cowpea system, integrated (organic + inorganic) and organic nutrients established its superiority over fertilizers alone in the second crop cycle. Direct and residual effect of 40 kg S/ha was found perceptible on brassica and cowpea, respectively. FYM alone and INM had more residual effect than use of inorganic nutrients.

## REFERENCES

Bodake, P.S. and Rana, D.S. 2009. Evaluation of Jatropha *(Jatropha curcas)* and castor *(Ricinus communis)* cake as a source of nutrients and soil amendment in spring sunflower (*Helianthus annuus)* –maize *(Zea mays)* sequence. *Indian Journal of Agronomy* **54**(3): 284–290.

Melero, S., Madejon, E., Ruiz, G. C. and Herencia, G. F. 2007. Chemical and biochemical properties of clay soils under dryland agriculture system as affected by organic fertilization. *European Journal of Agronomy* **26**: 327–334.

Mirsa, S. K. 2003. Effect of sulphur and potassium on yield, nutrient uptake and quality characteristics of mutard (*Brassica juncea* L.) in Udic Haplustepts of Kanpur. *Journal of the Indian Society of Soil Science* **51**(4): 544–548.

Palsaniya, D.R. and Ahlawat, I.P.S. 2009. Sulphur management in pigeonpea *(Cajanus cajan)*–wheat (*Triticum aestivum)* cropping system. *Indian Journal of Agronomy* **54**(3): 272–277.

Panwar, A.S. 2008. Effect of integrated nutrient management in maize (*Zea mays* L.)-mustard (*Brassica campestris* var. *toria*) cropping system in mid-hills altitude. *Indian Journal of Agricultural Sciences* **78**(1): 27–31.

Rana, D.S. and Pachauri, D.K. 2001. Sensitivity of zero erucic acid genotypes of *Oleiferous brassica* to plant population and planting geometry. *Indian Journal of Agronomy* **46**(4): 736–741.

Rana, D.S. 2002. Yield, yield attributes, nutrient uptake, nitrogen use efficiency and economics of *Oleiferous brassica* as influenced by time of sowing and fertility levels. *Indian Journal of Agricultural Sciences* **72**(9): 519–524.

Rana, D.S. and Giri, G. 2006. Influence of nitrogen and sulphur on canola and non-canola type rapeseed-mustard. *Annual Report,* Division of Agronomy, IARI, New Delhi pp. 53–54.

Rana, D.S., Giri, G. and Pachauri, D.K. 2007. Direct and residual effect of phosphorus and sulphur on yield trend, system productivity, economics and balance sheet of Indian mustard (*Brassica juncea*)-sunflower (*Helianthus annuus*)-urdbean (*Vigna mungo*) cropping system. *Indian Journal of Agricultural Sciences* **77**(7): 408–414.

Thakur, K.S., Kumar, A. and Mannya Sandeep 2005. Performance of promising varieties of gobhi sarson (*Brassica napus*) at different nitrogen levels. *Indian Journal of Agronomy* **50**(1): 67–69.

Walia, S.S. and Kler, D.S. 2008. Growth and nutrient uptake by wheat as influenced by organic and chemical sources of nutrient in soybean-wheat sequences. *Indian Journal of Ecology* **35**(1): 35–37.