An overview of genetic variability and gene action to improve yield of *Brassica napus*

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Abstract: Edible oil is an important constituent of our daily diet. Brassica seed oil has been important source of edible oil in Indo-Pak subcontinent especially Pakistan. The demand for oil seed is increasing due to the alarming increase in population, changing food habit and increase in per capita consumption of edible oil due to changing food habits of peoples. There is need to increase edible oil production through improving the crop plant potential. The present review will provide it reader the information about the use of conventional breeding for improving the yield of canola. It was concluded that broad sense heritability, heterosis, SCA, dominant gene action and heterobeltiosis may be used to develop potential hybrids. While GCA, genetic advance, narrow sense heritability and additive gene action may be used for developing synthetic varieties of canola.

[Abbas HG and Q. Ali. **An overview of genetic variability and gene action to improve yield of *Brassica napus*..** *Nat Sci* 2015;13(4):28-36]. (ISSN: 1545-0740). http://www.sciencepub.net/nature. 5

Keywords: *Brassica napus*, SCA, GCA, heterosis, heterobeltiosis, additive, dominant

Introduction

The economy of Pakistan is agro, based and majority of its people are dependent entirely upon this sector. The significant progress in agriculture sector has been achieved in the production and improvement of some important crops such as wheat, cotton, sugarcane, rice and corn. About 1.7 million tones is required to meet the domestic needs of the commodity of which 0.5 million tones is contributed by the local growers while the remaining 1.2 million tones is required to be imported to bridge the gap between the local production and consumption. Pakistan is lucky to have a over dozen oilseed crops, of which it can afford to grow one or the other in all the seasons of year. Despite their importance in our national economy and trade, the oilseed crops in general, are termed as “Miner/ Marginal crops”. The status and approach is indirect result of constant by neglecting the oilseed crops as well as agronomic sector. The present crisis demands much attention for the improvement of oilseed crops. Local production of oil, meet our needs only about 606 thousand tons out of which share of rapeseed/mustard is 68 thousand tons and Canola contribution is 6 thousand tons and sunflower share is 101 thousand tons and share of cotton is 431 thousand tons (Anonymous, 2013-14). The production of edible oil in Pakistan is very low as compared with other advance world countries. The main reason for low production of edible oil is due to less attention for oil seed and genetic improvement of oil seed crops. The more alarming indication is that the gap between production and consumption of edible oil increasing day by day. Genetic improvement could contribute significant to improve the situation. It is necessary to take important measure to improve the production potential of domestic source. The development of high yielding Brassica genotypes needs serious attention for improvement to overcome the shortage of edible oil. The improvement through breeding can be made successful by knowing the exact contribution of seed yield and its components.

Rape seed and mustard are the major contributor’s after cotton to the local vegetable oil production and thus improved, can be helpful to some extant in bringing up the gap between production and consumption. Moreover, due to direct competition of canola with wheat and rabbi fodders the area and inputs are usually squeezed for Canola. Keeping in view the above facts Govt. of Pakistan is trying to cut short the imports and to increase in area and production of various oil seed crops. Existing *Brassica napus* varieties are low yielding and late in maturity. This situation urges to breed the varieties with high productivity and early maturity. It is also requirement of the time to develop varieties with shattering, insect pests and disease resistances. Among these, the late maturity in *Brassica napus* needs high humidity that increases the vegetative growth and attracts insects while the maturity is induced to high temperature in March that increases the percentage of shriveled seeds, undeveloped seeds and sterile siliqua. Therefore, the evaluation of the varieties in *Brassica napus* that mature physiologically earlier is required. The information on the genetic control and inheritance on phonological traits is sparse. The improvement through breeding can be made successful by knowing the exact genetic behavior by creating genetic variability in *Brassicas* especially in *B. napus.*

Conventional breeding to improve canola yield

Genetic variability and gene action

Yadava *et al*. (1985) found significant variability among the genotypes for all the characters under observation, particularly for plant height, number of siliqua per plant, number of siliqua on the main shoot, number of secondary branches per plant and seed yield. Heritability estimates ranged from medium to high, except for oil content. Leon (1991) reported that mixtures of cultivars out-yielded cultivars by 6%. The F_1s out-yielded cultivars (15%), cultivar mixtures (by 8%) and Syn_1 (by 6%). The F_1 mixtures out-yielded F_1s surpassed cultivars by 4%, but yielded less than expected based on the parental and F_1 results. Malik *et al*. (1995) reported additive gene affects were important for plant height, number of primary and secondary branches, and number of siliqua on the main shoot. Heritability estimates were high for number of primary and secondary branches, oil content, whereas they were low for all other characters. Yadav and Yadav (1995) found that both additive and dominance genetic components were important for seed yield and yield components in *Brassica campestris* var, toria. However, the magnitude of dominance components was larger than additive components for all the traits. Uddin *et al.* (1995) found that considerable genotypic and phenotypic variation occurred for 1000-seed weight, seed yield per plant. Heritability values was high for 1000-seed weight and genetic analysis revealed that seed yield per plant had high positive effects and 1000-seed weight days taken to maturity and plant height had negative effects on seed yield per plant. Patel *et al*. (1996) concluded that non-additive gene action appeared to predominate for all characters except days taken to maturity, which was governed by additive gene action. Brown *et al.* (1996) found low values for narrow sense heritability were caused by large environment interactions of dominance over additive gene effects. Juska *et al*. (1997) discussed relationship between the genetic variation of crop plants and the ecological sustainability. The history of *B. napus* and *B. compestris* were studied to illustrate their potential and pedigree and cluster analysis are used to evaluate genetic diversity as well as its changes through time. Das *et al.* (1998) observed high genetic variability for siliqua/plant, number of secondary branches/plant, 1000-seed weight and plant height, indicating predominance of additive gene action in the inheritance of these traits.

Sheikh and Singh (1998) found that additive genetic variance was more important for plant height and length of siliqua for which a high estimate of heritability was also observed. Satwinder *et al.* (1998) revealed that both additive and non-additive components of genetic variance were significant for seed yield and seed size. Additive gene effects were predominant for seed yield and oil contents. Oil contents were controlled by maternal effects. Anil *et al*. (1998) evaluated ten physio-morpological parameters from different genotypes of *Brassica napus*. All parameters were positively correlated with seed yield; seeds per pod and siliqua per plant, the parameters of *B. napus* were less correlated with seed yield than *B. juncea.* Kumar *et al.* (1998) evaluated the inheritance of yield components in *Brassica juncea*. Dominant gene effects were found for number of secondary branches, length of main raceme, plant height, primary branches, secondary branches and siliqua on main raceme. Individual digenic epistasis was observed in both crosses. Kumar *et al.* (1998) carried out Diallel analysis, with six inbred lines of Toria (*Brassica campestris* L. var. Toria), indicated the presence of both additive and non-additive genetic components with the latter being more important for length of main raceme and 1000-seed weight. The ratio ($\sqrt{H1/D} = 0.05$) showed the presence of over-dominance for all the traits. Xu and Zhu (1999) reported a method for predicting potential heterosis of offspring of crop hybrids by an additive, dominance and additive × additive model (ADAA). By using unbiased predicators of additive and dominance, as well as additive × additive effects, general formulae for predicating mid-parent heterosis over the epistasis heterosis could play an important role in the use of heterosis. Varsha *et al*. (1999) studied the nature of additive, dominance, additive × additive, additive × dominance and dominance × dominance gene effects in two crosses, viz. ABU ×GS63 and ABU × IRMA in *Brassica napus*. The simple additive-dominance and digenic epistatic models both additive and dominance gene effects were important in the genetic control of seed yield, seed weight, pod number, plant number, plant height and days to flowering in both crosses. In addition to this all three types of non allelic interaction were observed ABU × IRMA.

Kim *et al.* (1999) and Krzymanski *et al.* (1999) evaluated that GCA effects of the four characters were highest in the largest parent. Broad sense heritability was generally high. Width of midrib had highest heritability. Malik *et al.* (1999) revealed that a lot of variability existed among the various accessions tested which have the potential to use for genetic improvement of *Brassica* species. Varsha *et al.* (1999) reported that all the three types of non-allelic interactions were observed for seed yield in cross ABU x GS63 and for plant height in a cross ABU x IRMA. The nature of gene effects seems to be influenced by seed yield in exotic x indigenous cross. Sirohi and Kutty (2000) evaluated the presence of additive gene action in these characters indicated the possibility of fixing these traits by selection methods in the later generations of the hybrid progeny.

Omholt *et al.* (2000) showed how the phenomena of genetic dominance, over dominance, additive, and epitasis are generic features of simple diploid gene regulatory networks. It is found that genetic dominance as well as over dominance may be intra as well as interlocus interaction phenomenon. It appears that in the intra as well as the interlocus case there is considerable room for additive gene action. Luhs *et al.* (2000) derived F_1 material from crosses between dark seeded high erucic acid rapeseed lines and true breeding yellow seeded *Brassica napus*. Both inbred and double haploid lines were generated. The genetic segregation was show that seed colour to be inherited in additive manner.

Larik and Rajput (2000) found that heritability showed high estimates (ranging from 97.70 to 60.24%) for all the traits indicating the involvement of additive gene action. Dry matter yield per plant, seed per siliqua and plant height exhibited low genetic advance irrespective of their high heritability estimates probably due to non-additive gene action. Khulbe *et al.* (2000) reported maximum variability for seed yield. All the characters except oil contents exhibited high heritability with high or moderate genetic advance, suggesting the rule of additive gene action in conditioning the traits. Non-additive gene action appeared to influence the expression of days taken to maturity. Ono and Takahata (2000) suggested that dominant gene had a positive effect on shoot regeneration. Non-allelic interaction and average maternal effect were not detected.

Larik and Rajput (2000) concluded that dry matter yield per plant, seeds per siliqua and plant height exhibited low genetic advance irrespective of their high heritability estimates, probably due to non-additive gene (dominance and epistasis) effects. In the basis of selection, it is concluded that branches per plant and siliqua per plant are the most important yield components. Lakshmi *et al.* (2001) found the additive effect to be more important in the inheritance of days taken to 95 % flowering, seed yield per plant, 1000-seed weight and oil content, have additive effects for days taken to 50 % flowering, days taken to 75 % maturity, seed yield per plant and oil content, dominance for days taken to 75 % maturity seed yield per plant and oil content and dominance × dominance for days taken to 50 % flowering and days to 75 % maturity and 1000-seed weight. Schierholt *et al.* (2001) suggested that variation in oleic acid could be explained by 2 mutations, one of them was expressed mainly in the seeds while other increase oleic acid contents not only in the seed but also in the roots and leaves. Both loci showed additive effect.

Ghosh and Gulati (2001) suggested the importance of additive gene action for their inheritance. Roa and Gulati (2001) reported that heritability may be used for selecting higher yielding canola genotypes. Yan *et al.* (2001) found significant inter-parental difference were also observed in fiber content of the hull, oil content of the seed and tannin content in the embryo, 1000-seed weight and yellowness of the seed. Kant and Gulati (2001) reported that additive gene effects were found to be more important in the inheritance of DTF, SYPP, TW and OC, additive × additive of DFP, DTM, SYPP and OC, dominance for DTM, SYPP and OC and dominance x dominance for DTF, DTM and TW. Ramsay *et al.* (2001) reported that evidence of additive × dominance and dominance × additive epistasis for neck length and hardness. Significant, constant reciprocal differences were found and these were particularly large for neck length and growth cracks. Ali *et al.* (2002) suggested that these yield components may be good selection criteria to improve seed yield of winter type rapeseeds.

Tukamuhabwa *et al.* (2002) found significant variation of wr +vr and wr-vr over arrays, suggestion epistatic gene action. Similarly results from a joint regression coefficient over replications were significantly ($p< 0.05$) different from unity and zero, suggesting presence of non-allelic interaction of gene. The intercept was positive, suggesting partial dominance for the shattering trait. Iqbal *et. al.* (2003) genetic analysis revealed that the characters like days taken to flowering and erucic acid have shown the additive type of gene action. So far as the regression analysis is concerned the non-significant deviation of the regression line from unit slope indicated the absence of non-allelic interaction, which was presented in all the characters.

Nassimi *et al.* (2006) revealed the importance of both additive and non-additive genetic variability suggesting the use of integrated breeding strategies which can efficiently utilize the additive as well as non-additive genetic variability. Khan *et al.* (2006) suggested that higher values of heritability coupled with high genetic advance for protein contents indicate the effectiveness of selection for this trait due to additive component of gene action. Zhang and Zhou (2006) found no significant gene interaction for plant height, stem width, number of branches, length of main raceme, number of seeds per pod and 1000-seed weight. In partial correlation analysis, numbers of pods per plant, number of seeds per pod and 1000-seed weight were positively correlated with seed yield per plant. On the other hand, length of pod was negatively correlated ($r = -0.69$) with seed yield per plant. It was shown that the four quality traits, i.e. erucic acid, glucosinolate, oil content, and protein content, had heritability values of 0.614, 0.405, 0.153 and 0.680 respectively. Oghan, *et al*. (2007) found both additive and non-additive gene effects were involved in the control of days to initial flowering, plant height, number of branches and 1000 seed weight, with the first more pronounced. For the genetic control of seed yield and oil contents both additive and non-additive gene effects were equally important. Broad sense heritability was high for all traits (42 % up to 91.5 %). Traits as 1000 seed weight and number of seed/pods had moderate narrow sense heritability (38.66 % and 43.37 % respectively). Genetic advance and additive gene action may be used for selection criteria to improve oil yield in canola (Ali *et al*. 2010).

Specific Combining Ability (SCA) and General Combining Ability (GCA)

Pazczola *et al.* (1993) intercrossed the varieties Bolko, Tor, Diadem, and Arabella. Panter and Libravo in one set of Diallel crosses and the varieties BOH1491 (Bor), Falcon, Tapidor, Otello and Lircus and another set. There were significant SCA effects in some crosses for all traits. The highest heterosis was found for seed and oil yield. Yadav *et al.* (1992) evaluated that some varieties were identified as good combiner for seed yield, length, earliness, siliqua length, 1000 seed weight. Some varieties emerged as good combiners for plant height, primary branches, secondary branches and oil contents. Havetinek (1993) found that GCA effects were greater than SCA ones. Darmor had the highest GCA for number of seed /siliqua, siliqua length and 1000-seed weight, while Sonata had the highest GCA for oil contents. SCA for seed weight/plant was highest in Sonata × SL502 which had the greatest heterosis for this trait. Krzymanski *et al*. (1994) found that SCA for seed yield was significant in the first generation but not in the second. Significant heterosis for seed yield relative to the better parent was seen in 9 crosses in the first generation but not in the second. Luczkiewicz (1996) reported that GCA effects and additive gene action were significant for all the traits except seed weight/ plant. Dominance effects were not significant. The highest heritability coefficient (in narrow sense) was obtained for number of branches/plant.

Thakur *et al.* (1997) and Rao and Gulati (2001) suggested the importance of both additive and dominance components of variation. Estimates of heterosis over better parent (BP) for the various traits were significant for seed yield (-14.8 to 82.8), primary branches (-26.0 to 193.6%) and siliqua per plant (-2109 to 162.6%). The cross GSB7027 × HNS8803 gave highest positive heterosis for seed yield per plant. Pietka *et al.* (1998) reported that effect of GCA and SCA effects of reciprocal effects in F_1 generation were highly significant. Winter hardness was shown to a complicated character whose genetic control depends on additive effects of parent, interaction of parental genotype and maternal cytoplasm. Verma and Kushwaha (2000) and Satija *et al.* (2001) studied the variances due to general combining ability (GCA) and specific combining ability (SCA) to asses the additive and non additive gene action involved in the inheritance of 9 characters in 8 parents and F_1 hybrids of *Brassica juncea*. The parents shown higher GCA effects for seed yield and other characters.

Sanjeev *et al.* (2007) found that mean squares due to general combining ability (GCA) and specific combining ability (SCA) were significant for all the characters over the environments. The interaction of GCA and SCA with the environment was significant for all traits except heading (%). The dominant: additive variance ratio indicated preponderance of non-additive gene action for these traits. 'Golden Acre' and 'Pride of Asia' were best general combiners for markable yield and majority of component traits. The hybrids 'Golden Acre' × 'Pride of India', 'Golden Acre' × 'Pride of Asia' and 'Pride of India' × 'Pride of Asia' which were potential specific combiners also exhibited higher magnitude of heterosis for markable yield (33.39, 39.40 and 40.14 % respectively) and important horticultural traits can be considered as the potential hybrids for commercial exploitation. Ofori and Becker (2008) found maximum mid parent heterosis was 21.0% for FBY and 30.4% for DBY. Analysis of variance showed that genetic variance was mainly due to specific combining ability (SCA). The correlation between parental performance and general combining ability (GCA) was 0.42** for FBY and 0.53** for DBY. In conclusion, the amount of heterosis in crosses between European winter *B. rapa* cultivars is not very high on average, but can be up to 30% in the best crosses. Selection of parental combinations with high specific combining ability to produce synthetic cultivars can rapidly improve biomass yield.

Teklewold and Becker (2005**)** studied that general combining ability (GCA) effects were predominant in all traits except secondary branches and pods per plant. Specific combining ability (SCA) was significant for days taken to flowering, secondary branches, pods per plant, pod length, seeds per pod, 1000-seed weight and oil contents. Interaction effects of GCA × location were significant for all traits except days to flowering, days to maturity, and oil contents. All traits had significant SCA × location interaction effects. GCA effect for seed yield was positively correlated with F_1 performance (r = 0.77) and absolute mid-parent heterosis (r = 0.67). The presence of high levels of mid- and high-parent heterosis indicates a considerable potential to embark on breeding of hybrid or synthetic cultivars in Ethiopian mustard. Akbar *et al.* (2008) reported that RBN 96040 proved good general combiner for all the traits studied. KS-75 proved good general combiner for all the traits except plant height and primary branches plant^{-1}. The cross "RBN 96040/RBN 96038" was the best specific combiner for all the traits studied followed by "RBN 96038//DGL/SHIRALEE" which proved good specific combiner for most of the traits including seed yield plant^{-1}. Chapi *et al.* (2008) found that mean square (GCA)/mean square (SCA) ratio in all traits was significant owing to additive and non additive gene effect of above mentioned traits but non-additive gene studied and low narrow sense heritability showed that non-additive gene effects plays an important role in genetically control of these traits. Heterosis for all traits was negatively significant. Qi *et al*. (2008) found that additive × additive × environment interaction was the main factor, which controlled TN and LN of Chinese vegetable mustard. Raziuddin *et al.* (2006) studied that GCA was highly significant ($p <= 0.01$) for 50% flowering, number of primary branches/plant and number of pods raceme, while non-significant for maturity and plant height whereas SCA and GCA effects were highly significant for all traitsIt was concluded the it could be used to develop early maturing, medium height and high yielding lines. Marijanovic *et al*. (2007) studied positive heterosis for plant height was found in five cross combinations, for the height to the first lateral branch in two combinations and for the number of lateral branches in only one combination and for seed yield in three cross combinations. GCA and SCA may be helpful to select genotypes to develop synthetic and hybrids respectively for batter grain and quality maize (Ali *et al*. 2013; Ali *et al*. 2014abc).

Heterosis

Hirve *et al.* (1991) found highest heterosis for seed yield was obtained in the cross RAU RP4 × PR 18 (16%). RLM 198 × Varuna, RAU RP4 × Varuna and TM 7 × Varuna also gave good seed yield heterosis and gave high heterosis for other yield-contributing characters. In general crosses containing Varuna as one parent gave high heterotic values. Pradhan *et al.* (1993) found significant heterosis over better parent for single plant yield was recorded in USSR × Indian and synthetic × USSR crosses, followed by Indian × synthetic types. From the component character analysis, it was concluded that characters such as number of primary and secondary branches, number of siliqua per plant and siliqua density contributed significantly to heterosis for yield. Yield trails of 2 selected hybrids (Skorospielk 11 × RH30 and Donskaya IV × Varuna) over 2 growing season revealed 29.4 to 91.8% heterosis over BYP. Barua *et al.* (1993) studied 3 yield traits in 5 varieties representing 2 *Brassica napus* types and *B. campestris* var. toria along with their hybrids from a half-diallel set of crosses. Heterosis mainly due to non-additive gene effects was important for dry matter and seed yield/plant. The most heterosis crosses were BSHI × M27, B9 × PT 303 and PK × M 27. The result suggested that recurrent selection with full sib crosses be useful in improving yield. Gupta *et al.* (1993) studied higher degree of commercial heterosis (over the best open pollinated commercial variety) than hybrids using S_0 material, though $S_0 \times S_0$ crosses gave high commercial heterosis for yield in many cases. Ramsay *et al.* (1994) reported strong positive heterosis for dry matter yield with high yielding F_1 showing an improvement of more than 20% above the better parent.

Ali *et al*., (1995) reported that the correlation between genetic distance and heterosis was positive and highly significant for seed yield, No. of pods/plant and No. of seeds/pod. Clustering, based on yield and yield- components traits, and demonstrated that in inter-cluster heterosis was greater than intra-cluster heterosis in the majority of cases. Davik (1997) reported that better parent heterosis of dry matter yield and remarkable yield were found for the majority of hybrids, although for breeding purposes better parent heterosis was low and the majority of hybrids were generally inferior compared to their parents. Krzymansli *et al*. (1998) examined significant positive heterosis effects as compared to better parents were observed for 18 cross combinations. Average seed yield of hybrids as compared to parent mean was 124.7%. General combining ability effects for glucosinolates contents were low but significant for four lines. Significant SCA effects and positive heterosis occurred only is six and three combinations from forty-five examined. Wang *et al.* (1999) evaluated heterosis and combining abilities of 20 reciprocal crosses combinations of 5 double low rape (*Brassica napus*) cultivars showing high yield. Positive mean heterosis number of siliqua/plant i.e. 17.6% was highest, followed by seed number/siliqua and 1000-seed weight. Teklewold and Becker (2005) and Tanaka and Niikura (2006) studied relative high – parent heterosis for seed yield varied from 16 to 124% with a mean of 53%. General combining ability effects were dominant in all traits except secondary branches and pods per plant. Specific combining ability was significant for days taken to flowering secondary branches, pods per plant, pod length, seeds per pod, 1000 seed weight and oil contents. Interaction effects of GCA × location were significant for all traits except days taken to flowering, days to maturity, and oil contents. Akbar *et al.* (2007) studied heterosis and heterobeltiosis for different quantitative and results showed significant differences between F_1's and their parents for all traits studied except 1000-seed weight. KS75 and RBN96040 proved to be potential parents for most of the traits with highly significant maximum heterosis and heterobeltiosis for seed yield and siliqua per plant. These were followed by crosses KS75/RBN96038, RBN96040/RBN96038 and RBN96040/3/RAINBOW//DGL/ SHIRALEE for seed yield and some other yield components. So these cross combinations must be given due to consideration while constituting commercial hybrids and finding out transgressive segregants in late segregating generations. Heterosis and heterobeltiosis may be used for the improvement of oil contents, carbohydrate percentage, protein percentage in maize (Ali *et al*. 2013; Ali *et al*. 2014abc).

Conclusion

It was concluded from all above discussion that the yield and quality of canola oil may be improved by using various gene action procedures. The use of conventional breeding may help to produce higher yielding canola hybrids with good quality oil contents. Broad sense heritability, heterosis, SCA, dominant gene action and heterobeltiosis may be used to develop potential hybrids. While GCA, genetic advance, narrow sense heritability and additive gene action may be used for developing synthetic varieties of canola.

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3/10/2015