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Genetic variability, heritability and character association among yield and yield attributing traits in oats (*Avena sativa* L)

Mayank Chaudhary and SK Singh

Abstract

Thirty eight of diverse genotypes oat (*Avena sativa* L.) were evaluated to examine the genetic variability, heritability, genetic advance, correlation, path coefficient analysis and genetic divergence during rabi 2015-16. Observations were recorded for days to 50% flowering, plant height, number of leaves per plant, flag leaf area, number of tillers per plant, stem girth, number of green pods per spike, length of spike, leaf stem ratio, dry fodder yield and green fodder yield per plant. Analysis of variance revealed substantial amount of variability among the genotypes for all the characters under study, indicated wide spectrum of variability among the genotypes. High heritability coupled with high genetic advance were revealed number of leaves per plant, stem girth, number of green pods per spike, leaf stem ratio, dry fodder yield per plant and green fodder yield per plant, indicating the preponderance of additive gene effects for these traits and hence may prove useful for effective selection. Green fodder yield showed significant and strong positive correlation with plant height, flag leaf area, stem girth and dry fodder yield per plant at both genotypic and phenotypic level. Therefore, these characters are useful to the breeders in selecting suitable plant type. Path coefficient analysis exhibited high positive and direct influence of number of leaves per plant, dry fodder yield per plant, stem girth and flag leaf area towards green fodder yield. By improving number of leaves per plant, flag leaf area, stem girth and dry fodder yield per plant, the green fodder yield in oats might be improved. Those traits were influenced green fodder yield via other traits, should also be given importance while improving the green fodder yield in oats. The inter cluster distances were higher than intra cluster distances suggesting presence of high genetic diversity between lines of any two cluster than the lines present within the cluster. Cluster II is characterized by line having maximum number of prominent traits studied and contributed more towards divergence, so the direct selection for these would be helpful. The study provided the opportunity to identify genotypes to be used in future breeding programme.

Keywords: Correlation, cluster, genetic advance, genetic variability, heritability

Introduction

Oats (*Avena sativa* L.) originated from Mediterranean region, is an important dual (grain and fodder) purpose annual crop of rabi season. It belongs to family *poaceae* and ranks sixth in production among all cereal crops next to wheat, maize, rice, barley and sorghum in the world scenario. Among the oats genomes, white oats (*Avena sativa*) and red oats (*Avena byzantina*) are cultivated. All over the world, oats was cultivated over 10.29 million hectares with a production of 20.49 million tonnes. Oat is a constituent of break-fast cereal in most developed countries. The importance of oats in the biochemical and cosmetic industry is also on the rise (Tiwari and Cummins, 2009) [24]. Grain yield needs improved to increase the area under oats as an alternative crop especially during winter cultivation. Oats production has continuously decreased, whereas the demand for oats as a human food has increased because of its dietary benefits of the whole grain and β glucan content (Buerstmayr *et al.*, 2007) [8]. Since oats acreage is much lower than that of most other cereals, commercial efforts in oats breeding is also lower. It can able to tolerate biotic and abiotic stresses to a greater extent and is an alternative choice among the basket of crops for many regions to mitigate the current regime of climate change. Grain yield is the result of a number of complex morphological and physiological processes influencing each other and occurring in different growing stages (Akhtar *et al.*, 2011) [3]. In general, oats breeders select varieties based on grain yield and other desirable yield attributing traits, observed from heading to maturity. Agronomic traits have been the primary objective of oats breeders. Besides grain yield, yield components and quality traits, morphological, biological and phenological traits are also important for breeding

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programs. Considerable importance has been given to studies involving correlation of traits in breeding programs. The quantification and interpretation of these correlations may result in wrong decision making on selection strategies, since a high correlation can be the result of a third trait or a group of traits affecting these traits. This technique identifies and quantifies the existing correlation between two trait complexes. Plant breeders have measured and selected for agronomic traits (grain yield, plant height, heading date, pest and disease resistance as well as lodging), grain physical traits (groat and kernel weight, test weight, groat percentage and milling yield) and grain composition traits (protein, oil, β -glucan and phytochemicals) for many years (Peterson *et al.*, 2005) [20]. All these traits are affected by genetic and environmental factors (Doehlert *et al.*, 2001) [10]. Breeders also develop oats populations for variety development from crosses within regionally adapted germplasms (Achleitner *et al.*, 2008) [1]. Unfortunately, as compared with the other cereals such as wheat, maize, rice and barley, less attention has been given to oats. The first step in a breeding programme is to determine the amount of variation that is present in the characters of agronomic importance. Assessment of the genetic variability can be achieved using morphological measurements and phenotypic characterization. Pundhir *et al.* (2008) [21] studied the genotypic and phenotypic coefficients of variation, heritability, expected genetic advance and correlation and path-analyses in 36 genotypes of oats (*Avena sativa* L.) over four environments which revealed moderate to high estimates of heritability coupled with high genetic advance for most of the traits. Bahadur *et al.* (2009) [6] studied oats genotypes to determine the extent of variability for various fodder yield and quality traits under normal and late sown conditions where they found considerable variability existed for all the characters. Present study was undertaken to estimate the variability parameters, heritability, genetic advance, correlation, path coefficient analysis yield and yield attributing traits in oats genotypes.

Materials and Methods

The present study was carried out during Rabi, 2015-16 at Crop Research Centre (Chirodi) of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U. P.), (29° 04' N latitude and 77° 42' E longitude a height of 237 m above mean sea level), Uttar Pradesh Province, India. The region has a semi-arid sub-tropical climate with an average annual temperature of 16.8°C. The highest mean monthly temperature (38.9 °C) is recorded in May, and the lowest mean monthly temperature (4.5°C) is recorded in January. The average annual rainfall is about 665 to 726 mm (constituting 44% of pan evaporation) of which about 80% is received during the monsoon period. The predominant soil at the experimental site is classified as Typic Ustochrept. Soil samples for 0–15 cm depth at the site were collected and tested prior to applying treatments and the basic properties were low available nitrogen, low organic carbon, available phosphorus, available potassium medium and alkali in reaction. A total of 38 genotypes were evaluated under field condition using randomized complete block design with three replications. The observations were recorded for yield and its component characters *viz.*, days to 50% flowering, plant

height, total number of tillers per plant, stem girth (mm), number of green pods per spike, length of spike (cm), leaf stem ratio (w/w) and dry fodder yield per plant. The descriptive statistics were worked out. The estimates of variability parameters were worked out according to the method suggested by Lush (1940) [17]. Heritability in broad sense was estimated (Allard, 1960) [4] and expressed in percentage. Genetic advance as percent of mean was estimated by the method suggested by Johnson *et al.* (1955) [14]. Genotypic correlation coefficients between yield and its component traits were used for this analysis. By keeping yield as a dependent variable and the other traits as independent variables, simultaneous equations, which expressed the basic relationship between path coefficients, were solved to estimate the direct and indirect effects.

Results and Discussion

A comparative study of the genotypic and phenotypic coefficients of variation for most of the characters studied showed a relatively similar contribution of the genotypic variation in determining the phenotypic variation [Table 1]. The genotypic coefficient of variation ranged between (6.48) to (34.52) for days to 50% flowering and stem girth, respectively. The phenotypic coefficient of variation ranged between (7.58) to (34.61) for days to 50% flowering and stem girth, respectively. All the characters under study showed high heritability (> 60%) for namely, days to 50% flowering (73.18), plant height (85.34), number of leaves per plant (92.23), flag leaf area (95.78), number of tillers per plant (96.84), stem girth (99.84), number of green pods per spike (94.37), length of spike (93.22), leaf stem ratio (97.40), dry fodder yield per plant (96.94) and green fodder yield per plant (97.64).

Expected genetic advance expressed as percentage of mean was observed high (>20%) for number of leaves per plant (27.96), stem girth (23.93), number of green pods per spike (20.45), leaf stem ratio (39.10), dry fodder yield per plant (36.75) and green fodder yield per plant (49.85), while, moderate (10-20%) genetic advance as percentage of mean was recorded for days to 50% flowering (11.42), plant height (19.30), number of tillers per plant (10.57) and length of spike (15.74). Low genetic advance as percentage of mean (<10) was found for flag leaf area. However, the proportion of this variation that was genetic and proportion due to other causes could not be ascertained from the analysis of variance. High amount of genetic variability for many of these traits has also been reported earlier by Krishna *et al.* (2013) [16], Shinde *et al.* (2015) [22], Bind *et al.* (2016) [7] and Jaipal and Shekhawat (2016) [13].

The genotypic and phenotypic variances are of little meaning as they do not have any clear limit or ceiling and at the same time the categorization of the genotypic variance as low or high is difficult, rendering them unsuitable for comparison of two populations with desired precision when expressed in absolute values. To overcome this difficulty, the genotypic and phenotypic coefficient of variation, which are free from the unit of measurement, can be conveniently employed for making comparison between populations and different metric characters of population.

Table 1: Estimates of variability parameters for eleven characters in oat (*Avena sativa* L)

| Characters | Heritability % (broad sense) | Genetic Advance | Genetic Advance (as % of mean) | GCV (%) | PCV (%) |
|-----------------------------------|------------------------------|-----------------|--------------------------------|---------|---------|
| Days to 50% flowering | 73.18 | 10.91 | 11.42 | 6.48 | 7.58 |
| Plant height | 85.34 | 21.09 | 19.30 | 10.14 | 10.98 |
| No. of leaves per plant | 92.23 | 1.18 | 27.96 | 14.13 | 14.72 |
| Flag leaf area (cm ²) | 95.78 | 9.72 | 8.08 | 18.89 | 19.30 |
| No. of tillers per plant | 96.84 | 4.04 | 10.57 | 25.94 | 25.99 |
| Stem girth (mm) | 99.80 | 21.18 | 23.93 | 34.52 | 34.61 |
| No. of green pods per Spike | 94.37 | 19.57 | 20.45 | 20.21 | 20.81 |
| Length of spike (cm) | 93.22 | 8.95 | 15.74 | 17.97 | 18.61 |
| Leaf stem ratio (w/w) | 97.40 | 20.15 | 39.10 | 29.07 | 29.46 |
| Dry fodder yield per plant (g) | 96.94 | 24.06 | 36.75 | 25.05 | 25.41 |
| Green fodder yield per plant (g) | 97.64 | 29.37 | 49.85 | 29.40 | 29.76 |

Correlation between yield and its component characters

Correlation coefficients between all pairs of variables used in this experiment are shown in Table 2. The significant and positive correlation of green fodder yield per plant was observed with plant height (0.37), flag leaf area (0.46), stem girth (0.53) and dry fodder yield per plant (0.40), while exhibited negative but non-significance correlation of green fodder yield per plant with days to 50 percent flowering (-0.08), number of green pods per spike (-0.05) and leaf stem ratio (-0.03) and showed positive but non-significant correlation of green fodder yield per plant with number of leaves per plant (0.06), number of tillers per plant (0.13) and length of spike (0.19).

Days to 50 percent flowering revealed positive and significant correlation with plant height (0.31), number of leaves per plant (0.34), flag leaf area (0.26) and leaf stem ratio (0.27), positive and non-significant correlation with number of tillers per plant (0.09), number of green pods per plant (0.09) and length of spike (0.08) and non-significant negative association with stem girth (-0.07) and dry fodder yield per plant (-0.07) [Table 2]. Plant height exhibited significant and positive correlation with flag leaf area (0.60), number of green pods per spike (0.45), leaf stem ratio (0.38) and green fodder yield per plant (0.37), positive but non-significant association with number of tillers per plant (0.18), stem girth (0.10), length of spike (0.07) and dry fodder yield per plant (0.06) and non-significant but negative correlation with number of leaves per plant (-0.12). Number of leaves per plant showed positive significant correlation with stem girth (0.28), non-significant positive correlation with dry fodder yield per plant (0.09) and green fodder yield per plant (0.06) and negative non-significant association with flag leaf area (-0.03), number of tillers per plant (-0.02), number of green pods per spike (-0.11), length of spike (-0.06) and leaf stem ratio (-0.04). The above result suggested the possibility of selection of one of the above component character would result in the improvement of other characters. Nirmalakumari *et al.* (2013) [19] and Tang *et al.* (2014) [23] also observed significant and positive association of this character.

Flag leaf area had positive significant correlation with number of tillers per plant (0.32), stem girth (0.24), length of spike (0.26), dry fodder yield per plant (0.49) and green fodder yield per plant (0.46), non-significant but positive correlation association with number of green pods per spike (0.04) and negative non-significant correlation with leaf stem ratio (-0.05) [Table 2] These results are in conformity with the findings of Krishna *et al.*, (2013) [16] for fodder yield per plant. Number of tillers per plant noted positive significant association with stem girth (0.44) and length of spike (0.48),

positive non-significant correlation with number of green pods per spike (0.09), leaf stem ratio (0.03) and green fodder yield (0.13) and negative non-significant correlation with dry fodder yield per plant (-0.02). Stem girth recorded positive significant association with number of green pods per spike (0.33), length of spike (0.39) and green fodder yield per plant (0.53), positive but non-significant correlation with leaf stem ratio (0.01) and dry fodder yield per plant (0.17). Number of green pods per spike reported positive significant association with length of spike (0.51) and leaf stem ratio (0.29), positive non-significant correlation with dry fodder yield per plant (0.01) and negative but non-significant correlation with green fodder yield per plant (-0.05) [Table 2]. Length of spike was found positive significant association with leaf stem ratio (0.36) and positive but non-significant correlation with dry fodder yield per plant (0.08) and green fodder yield per plant (-0.19). Leaf stem ratio revealed positive significant association with dry fodder yield per plant (0.39) and non-significant negative correlation with green fodder yield per plant (-0.03). Dry fodder yield exhibited positive significant association with green fodder yield per plant (0.40). This was in agreement with the findings of Iannucci *et al.* (2011) [12], Hisir *et al.* (2012) [11] and Nirmalakumari *et al.* (2013) [19].

Among genotypic correlation the green fodder yield per plant Table 2 showed positive and significant correlation with plant height (0.36), flag leaf area (0.45), stem girth (0.51) and dry fodder yield per plant (0.39), while exhibited negative but non-significance correlation of green fodder yield per plant with days to 50% flowering (-0.04), number of green pods per spike (-0.04) and leaf stem ratio (-0.02) and revealed positive but non-significant correlation of green fodder yield per plant with number of leaves per plant (0.05), number of tillers per plant (0.12) and length of spike (0.12). Further, the present findings showed that estimates of PCV were generally higher than their corresponding GCV for all the character studied. These findings are similar in agreement with earlier reported by Ahmed *et al.* (2013) [2], Verma and Yadav (2013) [25], Avinash *et al.* (2014) [5] and Bind *et al.* (2016) [7]. The difference among the genotypic coefficient of variance and phenotypic coefficient of variance value for different characters indicated that the influence of environment in expressing the variability with traits. If this difference least, means the environment is much affecting in the variable performance of the characters. But if the difference is more, means there is much influence of environment in the expression of the traits.

Perusal on correlation among component characters revealed that strong associations among desirable component characters are present especially with number of tillers per

plant, number of green pods per spike and length of spike. Hence, selection criteria should consider all these characters for the improvement of yield. Undesirable association of some of the component characters might act as deterrent for

the formulation of a comprehensive selection programme involving these traits. So, while formulating a comprehensive selection programme, these factors must be considered with a caution.

Table 2: Estimates of correlation coefficient for genotypic (G) and phenotypic (P) levels among different characters in oat (*Avena sativa* L.)

| Characters | | Days to 50% flowering | Plant height | No. of leaves per plant | Flag leaf area (cm ²) | No. of tillers per plant | Stem girth (mm) | No. of green pods per spike | Length of spike (cm) | Leaf stem ratio (w/w) | Dry fodder yield per plant (g) | Green fodder yield per plant (g) |
|-----------------------------------|---|-----------------------|--------------|-------------------------|-----------------------------------|--------------------------|-----------------|-----------------------------|----------------------|-----------------------|--------------------------------|----------------------------------|
| Days to 50% flowering | G | 1.00 | 0.30** | 0.32** | 0.25** | 0.04 | -0.05 | 0.07 | 0.06 | 0.26** | -0.05 | -0.04 |
| | P | 1.00 | 0.31** | 0.34** | 0.26* | 0.09 | -0.07 | 0.09 | 0.08 | 0.27** | -0.07 | -0.08 |
| Plant height | G | | 1.00 | -0.11 | 0.59** | 0.16 | 0.09 | 0.41** | 0.05 | 0.36** | -0.08 | 0.36** |
| | P | | 1.00 | -0.12 | 0.60** | 0.18 | 0.10 | 0.45** | 0.07 | 0.38** | 0.06 | 0.37** |
| No. of leaves per plant | G | | | 1.00 | -0.01 | -0.02 | 0.25** | -0.16 | -0.05 | -0.03 | 0.07 | 0.05 |
| | P | | | 1.00 | -0.03 | -0.02 | 0.28** | -0.11 | -0.06 | -0.04 | 0.09 | 0.06 |
| Flag leaf area (cm ²) | G | | | | 1.00 | 0.31** | 0.22** | 0.03 | 0.25** | -0.03 | 0.48** | 0.45** |
| | P | | | | 1.00 | 0.32** | 0.24** | 0.04 | 0.26** | -0.05 | 0.49** | 0.46** |
| No. of tillers per plant | G | | | | | 1.00 | 0.43** | 0.08 | 0.41** | 0.02 | -0.02 | 0.12 |
| | P | | | | | 1.00 | 0.44** | 0.09 | 0.48** | 0.03 | -0.02 | 0.13 |
| Stem girth (mm) | G | | | | | | 1.00 | 0.30** | 0.30** | 0.01 | 0.17 | 0.51** |
| | P | | | | | | 1.00 | 0.33** | 0.39** | 0.01 | 0.17 | 0.53** |
| No. of green pods per spike | G | | | | | | | 1.00 | 0.49** | 0.27** | 0.05 | -0.04 |
| | P | | | | | | | 1.00 | 0.51** | 0.29** | 0.01 | -0.05 |
| Length of spike (cm) | G | | | | | | | | 1.00 | 0.30** | 0.04 | 0.12 |
| | P | | | | | | | | 1.00 | 0.36** | 0.08 | 0.19 |
| Leaf stem ratio | G | | | | | | | | | 1.00 | 0.37** | -0.02 |
| | P | | | | | | | | | 1.00 | 0.39** | -0.03 |
| Dry fodder yield per plant (g) | G | | | | | | | | | | 1.00 | 0.39** |
| | P | | | | | | | | | | 1.00 | 0.40** |
| Green fodder yield per plant (g) | G | | | | | | | | | | | 1.00 |
| | P | | | | | | | | | | | 1.00 |

*, **significant at 5% and 1% level, respectively

Path coefficient analysis

A perusal of the results on path coefficient revealed high positive direct effect for number of leaves per plant (0.59) followed by dry fodder yield per plant (0.56), stem girth (0.51) and flag leaf area (0.45) and maximum negative direct effect observed for number of green pods per spike (-0.18). Number of leaves per plant with positive direct effect revealed indirect positive effect for number of green pods per spike (0.35). Flag leaf area with positive direct effect exhibited indirect positive effect for number of green pods per spike (0.26). Positive correlation of green fodder yield per plant with flag leaf area is in confirmation of the earlier workers Choubey and Lodhi (2008) [9] and Krishna *et al.* (2013) [16]. Number of tiller per plant with positive direct effect revealed indirect positive effect for number of leaves per plant (0.35). Stem girth with positive direct effect noted indirect positive effect for number of leaves per plant (0.45), number of tiller per plant (0.21) and number of green pods per spike (0.46). Number of green pods per spike with positive direct effect observed indirect positive effect for number of

leaves per plant (0.52). Leaf stem ratio with positive direct effect reported indirect positive effect for number of green pods per spike (0.37). Dry fodder yield per plant with positive direct effect was found indirect positive effect for plant height (0.27), number of leaves per plant (0.26), flag leaf area (0.43), number of tiller per plant (0.32) and stem girth (0.58) [Table 3].

Partitioning of the correlation coefficients in to direct and indirect effects was done at the genotypic level results is presented in Table 3. A critical perusal of result in the table revealed that number of leaves per plant had the maximum direct positive effect (0.58) followed by dry fodder yield per plant (0.54), stem girth (0.50) and flag leaf area (0.43). At genotypic level also the estimates of direct and indirect effects were generally similar to those exhibited at phenotypic level with little variation in magnitudes. Positive correlation of green fodder yield per plant with dry fodder yield per plant was consonance with the findings of Mushtaq *et al.* (2013) [18], Nirmalakumari *et al.* (2013) [19], Krishna *et al.* (2013) [16] and Jaipal and Shekhawat (2016) [13].

Table 3: Path coefficient analysis showing the direct and indirect effect of eleven characters on the green fodder yield at genotypic and phenotypic level of oat (*Avena sativa* L)

| Characters | | Days to 50% flowering | Plant height (cm) | No. of leaves per plant | Flag leaf area (cm ²) | No. of tillers per plant | Stem girth (mm) | No. of green pods per spike | Length of spike (cm) | Leaf stem ratio (w/w) | Dry fodder yield per plant (g) | Correlation with green fodder yield per plant (g) |
|-----------------------------------|---|-----------------------|-------------------|-------------------------|-----------------------------------|--------------------------|-----------------|-----------------------------|----------------------|-----------------------|--------------------------------|---|
| Days to 50% flowering | G | 0.03 | 0.07 | 0.05 | 0.01 | 0.03 | -0.05 | -0.04 | 0.03 | 0.05 | -0.04 | -0.04 |
| | P | 0.04 | 0.09 | 0.05 | 0.05 | 0.07 | -0.03 | -0.05 | 0.07 | 0.04 | -0.08 | -0.08 |
| Plant height (cm) | G | -0.05 | 0.08 | 0.04 | 0.05 | -0.07 | 0.15 | -0.05 | 0.02 | 0.04 | 0.26 | 0.36** |
| | P | -0.06 | 0.09 | 0.03 | 0.18 | -0.05 | 0.13 | -0.06 | 0.04 | 0.06 | 0.27 | 0.37** |
| No. of leaves per plant | G | 0.25 | -0.08 | 0.58 | -0.01 | 0.33 | 0.44 | 0.47 | -0.03 | -0.01 | 0.25 | 0.05 |
| | P | 0.27 | -0.09 | 0.59 | -0.08 | 0.35 | 0.45 | 0.52 | -0.08 | -0.01 | 0.26 | 0.06 |
| Flag leaf area (cm ²) | G | -0.04 | 0.04 | 0.03 | 0.43 | 0.02 | 0.13 | -0.04 | 0.01 | -0.04 | 0.45 | 0.45** |
| | P | -0.05 | 0.05 | 0.07 | 0.45 | 0.03 | 0.12 | -0.05 | 0.03 | -0.08 | 0.43 | 0.46** |
| No. of tillers per plant | G | 0.02 | 0.06 | 0.05 | 0.01 | 0.06 | 0.23 | -0.09 | 0.08 | 0.06 | 0.32 | 0.12 |
| | P | 0.04 | 0.07 | 0.04 | 0.06 | 0.07 | 0.21 | -0.03 | 0.09 | 0.07 | 0.32 | 0.13 |
| Stem girth (mm) | G | -0.01 | 0.02 | -0.04 | 0.01 | -0.04 | 0.50 | -0.04 | -0.06 | 0.02 | 0.59 | 0.51** |
| | P | -0.02 | 0.04 | -0.01 | 0.05 | -0.03 | 0.51 | -0.01 | -0.02 | 0.03 | 0.58 | 0.53** |
| No. of green pods per spike | G | 0.07 | -0.03 | 0.32 | 0.25 | 0.01 | 0.45 | -0.15 | 0.04 | 0.36 | -0.04 | -0.04 |
| | P | 0.08 | -0.05 | 0.35 | 0.26 | 0.01 | 0.46 | -0.18 | 0.05 | 0.37 | -0.06 | -0.05 |
| Length of spike (cm) | G | 0.02 | 0.04 | 0.01 | 0.02 | 0.04 | 0.16 | -0.09 | 0.02 | 0.08 | 0.02 | 0.12 |
| | P | 0.03 | 0.06 | 0.01 | 0.10 | 0.03 | 0.15 | -0.11 | 0.08 | 0.09 | 0.04 | 0.19 |
| Leaf stem ratio (w/w) | G | -0.04 | 0.03 | 0.02 | -0.01 | -0.04 | 0.08 | -0.07 | 0.03 | 0.13 | -0.02 | -0.02 |
| | P | -0.05 | 0.04 | 0.01 | -0.01 | -0.03 | 0.07 | -0.08 | 0.04 | 0.17 | -0.03 | -0.03 |
| Dry fodder yield per plant (g) | G | 0.08 | -0.07 | -0.04 | 0.02 | 0.02 | 0.09 | 0.02 | -0.03 | -0.07 | 0.54 | 0.39** |
| | P | 0.09 | -0.09 | -0.03 | 0.10 | 0.02 | 0.09 | 0.03 | -0.02 | -0.08 | 0.56 | 0.40** |

Residual values (G) = 0.32, Residual values (P) = 0.40 *, **significant at 5% and 1% level, respectively Bold value indicate direct effects

Thirty eight genotypes, included in study were grouped into 8 clusters. The clustering pattern of the genotypes has been presented in Table-4. A total of 8 genotypes fell into cluster

III, 7 genotypes in cluster I and II, 5 genotypes in cluster IV and VIII, 4 genotypes in cluster V and 1 genotype in cluster number VI and VII.

Table 4: Distribution of thirty eight genotypes of oat (*Avena sativa* L)

| Clusters number | No. of genotypes | Genotypes |
|-----------------|------------------|--|
| I | 7 | JHO 99-2, UPO -202, EC -246184, UPO-94, UPO-201, UPO-240, EC-246197 |
| II | 7 | EC- 529095, UPO -06-1, EC -246207, EC-246299, EC-576061, UPO- 276, JHO 2003-78 |
| III | 8 | NDO-1, Kent, OS-7, JHO-2001-1, UPO -272, AOS- 1-1, UPO -268, JHO- 2002-6 |
| IV | 5 | JHO -2002-7, OS -6, JHO-2004-1, OL -125, JHO-2000-4 |
| V | 4 | UPO-2005-1, EC -1176404, JHO -851, EC 246198 |
| VI | 1 | EC-246128 |
| VII | 1 | EC-2676176 |
| VIII | 5 | EC -246199, JHO -822, EC- 246206, EC-246205, EC-246190 |

Inter and intra-cluster distance and Cluster mean

Maximum inter cluster D^2 value (10.66) was recorded between cluster III and II. Whereas the minimum average inter cluster D^2 value (0.02) was recorded between cluster II and I. The intra cluster divergence were found to range between 2.69 for cluster I, 6.97 for cluster II, 7.04 for cluster III, 5.17 for cluster IV, 3.29 for cluster V, 3.77 for cluster VI, 3.84 for cluster VII and 3.27 for cluster VIII. The maximum inter cluster D^2 value indicated that genotypes of cluster III and II are not so closely related whereas the genotypes of cluster II and I are closely related. It is apparent therefore, the genotypes of various clusters do not differ so significantly with regards to their relative genetic distance as indicated from the low variation of D^2 values [Table 5].

The cluster mean calculated for eleven characters under study have been presented in Table-6. Days to 50% flowering showed highest mean for cluster number IV (100.20) and lowest mean for cluster number V (85.03). Plant height revealed highest mean for cluster number IV (123.50) and lowest mean for cluster number VI (7461). Number of leaves per plant exhibited highest mean for cluster number VI (5.40)

and lowest mean for cluster number III (3.81). Flag leaf area had highest mean for cluster number VIII (33.67) and lowest mean for cluster VI (16.96). Number of tillers per plant recorded highest mean for cluster number VII (11.99) and lowest mean for cluster number VI (4.00). Stem girth estimated highest mean for cluster number VII (8.00) and lowest mean for cluster number V (4.30). Number of green pods per plant noted highest mean for cluster number IV (29.80) and lowest mean for cluster number V (19.25). This view point has been supported by the work of Krishna *et al.* (2014) [16], Jaipal and Shekhawat (2016) [13] and Kaur and Kapoor (2017) [15]. Length of spike was found highest mean for cluster number IV (30.20) and lowest mean for cluster number V (20.50). Leaf stem ratio observed highest mean for cluster number IV (0.35) and lowest mean for cluster number VI (0.18). Dry fodder yield per plant showed highest mean for culture number I (38.75) and lowest mean for cluster number VI (22.03). Green fodder yield per plant exhibited highest mean for cluster number VII (298.22 and lowest mean for cluster number VI (55.63).

Table 5: Average intra and inter cluster (D^2 value) distance in thirty eight genotypes of oat (*Avena sativa* L.)

| Cluster | I | II | III | IV | V | VI | VII | VIII |
|---------|------|------|-------|------|------|------|------|------|
| I | 2.69 | 0.02 | 0.07 | 2.27 | 1.72 | 1.64 | 1.76 | 2.12 |
| II | | 6.97 | 10.66 | 4.02 | 5.48 | 3.15 | 1.98 | 2.99 |
| III | | | 7.04 | 8.67 | 7.32 | 3.29 | 3.45 | 2.65 |
| IV | | | | 5.17 | 7.70 | 5.77 | 3.09 | 4.68 |
| V | | | | | 3.29 | 7.88 | 4.42 | 2.84 |
| VI | | | | | | 3.77 | 8.51 | 5.54 |
| VII | | | | | | | 3.84 | 7.67 |
| VIII | | | | | | | | 3.27 |

Bold values are intra cluster distances

Table 6: Clusters means values for eleven characters in oat (*Avena sativa* L.)

| Character/ Clusters | Days to 50% flowering | Plant height | No. of leaves per plant | Flag leaf area (cm ²) | No. of tillers per plant | Stem girth (mm) | No. of green pods per spike | Length of spike (cm) | Leaf stem ratio (w/w) | Dry fodder yield per plant (g) | Green fodder yield per plant (g) |
|------------------------|--------------------------|-----------------|-------------------------------|--------------------------------------|-----------------------------------|-----------------------|--------------------------------------|-------------------------|--------------------------|--------------------------------------|---|
| I | 91.65 | 105.25 | 4.21 | 26.59 | 6.90 | 5.10 | 20.45 | 23.71 | 0.20 | 38.75** | 166.23 |
| II | 98.55 | 104.45 | 4.07 | 23.32 | 6.39 | 5.60 | 24.50 | 24.57 | 0.27 | 23.64 | 126.86 |
| III | 97.25 | 113.76 | 3.81* | 24.33 | 9.07 | 5.80 | 20.50 | 23.13 | 0.24 | 26.28 | 141.98 |
| IV | 100.20** | 123.50** | 3.83 | 26.08 | 10.56 | 7.60 | 29.80** | 30.20** | 0.35** | 26.06 | 142.35 |
| V | 85.03* | 96.98 | 4.81 | 20.14 | 7.10 | 4.30* | 19.25* | 20.50* | 0.24 | 28.95 | 126.25 |
| VI | 95.87 | 74.61* | 5.40** | 16.96* | 4.00* | 6.00 | 25.00 | 22.00 | 0.18* | 22.03* | 55.63* |
| VII | 90.00 | 120.52 | 5.06 | 30.02 | 11.99** | 8.00** | 23.00 | 30.00 | 0.22 | 36.50 | 298.22** |
| VIII | 98.85 | 114.99 | 4.52 | 33.67** | 8.22 | 7.20 | 29.20 | 28.80 | 0.27 | 38.25 | 183.17 |

*Minimum cluster mean values **Maximum cluster mean values

Conclusion

The study helps in determining the positive and negative correlations among different traits and traits which can be utilized directly for selection of best performing genotypes for high green fodder yield. Path coefficient analysis measures the direct and indirect influence of variables on the green fodder yield and helps in selecting meritorious characters to be used in selection programme to get maximum yield. The relationships must be taken into consideration as a change on one during selection might lead to change in other performing traits. The study also helps in understanding the diversity available in the genotypes selected and helps in selection and improvement of desirable traits to be used or transferred during crossing program.

High heritability coupled with high genetic advance were revealed number of leaves per plant, stem girth, number of green pods per spike, leaf stem ratio, dry fodder yield per plant and green fodder yield per plant, indicating the preponderance of additive gene effects for these traits and hence may prove useful for effective selection. Green fodder yield showed significant and strong positive correlation with plant height, flag leaf area, stem girth and dry fodder yield per plant at both genotypic and phenotypic level. Therefore, these characters are useful to the breeders in selecting suitable plant type. Path coefficient analysis exhibited high positive and direct influence of number of leaves per plant, dry fodder yield per plant, stem girth and flag leaf area towards green fodder yield. By improving number of leaves per plant, flag leaf area, stem girth and dry fodder yield per plant, the green fodder yield in oats might be improved. Those traits were influenced green fodder yield via other traits, should also be given importance while improving the green fodder yield in oats. Genotype from the same geographical region fell into different clusters and vice-versa. This suggested that selections of parents for hybridization should be on genetic diversity rather than on the geographical areas. The percent contribution of Green fodder yield per plant had maximum

contribution towards the genetic divergence followed by days to 50% flowering, plant height, dry fodder yield per plant, number of leaves per plant, number of tillers per plant and length of spike. Genetic divergence study suggested that crosses between the genotypes of cluster VI (EC-246128), cluster VII (EC-2676176) and genotypes of cluster V (UPO-2005-1, EC-1176404, JHO-851 and EC-246198) for getting better hybrid vigour in F_1 or better hybrids and also for good recombinants in segregating population.

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