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GENOTYPE X ENVIRONMENT INTERACTIONS IN OATS, AND THEIR IMPLICATION ON FORAGE OAT BREEDING PROGRAMMES IN PAKISTAN

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Thirteen oasts genotypes were evaluated for their forage yield potenital at 4 locations and for 4 years. Estimates of various types of genotype x environment interactions were obtained from forage oats performance tests. Genotype x locations and genotype x year interaction effects were significant, but thier variance components were small compared with the second order interaction indicated that oat genotypes responded quite differently to different environmental conditions. This response was not accounted for by either year or location suggesting that the three provinces under study should be divided into sub-areas on the basis of variation in rainfall, temperature, soil types, and soil fertility in order to minimize genotype x environments interaction for an efficient forage oat evaluation programme.

Key words: *Avena sativa,* Oat, Genotype, Environment, Breeding, Forage.

Introduction

Forage oats are grown throughout Pakistan during winter season under a wide variety of soil and climatic conditions. The variation in environmental conditions in different agro-ecological regions of the country has been well known to the plant breeders. The fluctuations in rainfall and temperature are not consistent and predictable from year to year as well as from location to location. Fertility status and soil types also vary throughout the country. Serious losses in forage yields due to drought, disease, and insects are common throughout the country.

Horner and Frey [1] reported that dividing the Iowa State into 2,3,4, and 5 bus-areas would reduce variety x location interaction effects by 11, 21, 30, and 40%, respectively and hence would increase the efficiencies of the state wide oat performance trials.

Liang *et al.* [2] studied genotype x environment interaction in wheat, barley, and oat and recommended to divide Knasas into 4 and 3 areas, for wheat and barley testing, respectively. Liang *et al.* [2] also concluded that it would not be necessary to divide the state into smaller areas for oat cultivar testing.

"Effectiveness of varietal testing programme is influenced by several factors. These factors include experimental designes, the number of locations, the number of years used to average variety means. Rasmusson and Lambert [3] Baker [4], and Kaltsikes [5] studies the optimum allocation of resources in varietal evaluation for barley, wheat, and fall rye, respectively, and concluded that changes in number of years and locations were more effective than changes in number of replications to enhance the efficiency of varietal evaluation procedures. Hussain *et al.* [6] studies allocation of resources in forage sorghum varietal evaluation and concluded that use of additional years, locations, are replications was effective in the reduction of genetic variance of genotype mean.

To evaluate the importance of genotype x environment interactions, De Pauw *et al.* [7] compared three cultivars of wheat, three cultivars of oats,and three cultivars of barley for four years at fiver locations in north western Canada. They concluded that cultivars showed differential responses in specific environments which can be used to determine areas of cultivars adaptation.

Five rape (*Brassica napus* L.) cultivars were compared by Brandel and McVetty [8] for three years at nine locations in Manitoba, Canada. It was concluded that increasing years was most effective in reducing the standard error of a cultivar mean followed by locations and replications.

In a study regarding genotype x environment interaction at twenty seven locations for five years, in Alberta, Canada, Kibite *et al.* [9]] suggested to divide Alberta into six rainfed and two irrigated areas.

The performance of 54 forage, dual, and grain types of sorghum were evaluated for forage yield, grain yield, and forage quality by Muhammad [10] at three locations for two years in Kansas, USA. It was observed that different sorghum types responded differently when grown under diverse environments.

Muhammad *et al.* [11] evaluated five maize cultivars for green fodder yield, dry matter yield, crude protein, and crude fibre contents for two years under three environments in Pakistan. The results of the study reveald that genotypes responded differently in different environments. It was concluded that the wide variations in the green fodder yield, dry matter yield, curde protein, and crude fibre contents at different environments was probably due to differences in the nature and condition of soil types, soil fertility, and climatic conditions.

Information is required as to whether forage oat varieties respond differently when planted under diverse environment interactions, and if so, how important such genotype x environment interaction might be in an oat variety evaluation and selection programme. The main objectives of the study were: (i) To estimate the magnitudes of various types of genotype x environment interactions in forage oat variety evaluation programmes in Pakistan; and (ii) Tmplications of these interactions on variety evaluation and selection procedures.

Materials and Methods

Thirteen genotypes of forage oats *viz.* DN-8, Algerian, W. No.11, Avon. Fulgrain, Sargodha-81, Cassia, Swan, PD2-LV65, Kent, Java Lahori, Fatua, and Eagle No.1 were planted in the second week of October and harvested in the middle of March at four locations. The locations were:

(i) Ayub Agricultural Research Institute (AARI) Faisalabad.
(ii) Agricultural Research Institute (ARI), Sariab, Quetta.
(iii) Agricultural Research Institute (ARI), Tandojam, and
(iv) National Agricultural Research Centre (NARC), Islamabad.

The experiments were grown from 1984 to 1987, inclusive. The average winter rainfall and temperature, and the soil type for the four locations are presented in Table1.

The varieties differend for a range of agronomic characteristics such as forage yield, maturity, lodging resistance, plant height and resistance to insects and diseases. A randomized block design with two replications was used at all locations in each year. The experiments were conducted in the winter seasons under irrigation and normal soil fertility conditions (75 kg nitrogen + 50 kg phosphorus per hectare).

The combined analysis of variance computed from four locations and four years were used to estimate components of variance. The forms of analysis of variance, mean squares, and corresponding expectations of mean squares were discussed by Miller *et al.* [12] and Comstock and Moll [13].

Information regarding the number of experiments which should be conducted to evaluate forage oat cultivars may be obtained from the calculation of expected variance of variety mean. The expected variance of a variety mean (Vx= green fodder yield tons/ha) from a series of replication experiments conducted over several locations and years was calculated as follows:

$$Vx = \sigma^2gy/y + \sigma^2gl/1 + \sigma^2gly/ly + \sigma^2e/rly$$

where, σ^2 gy = variance due to genotype x year, y = years, σ^2 gl = variance due to genotype x location, 1 = locations, σ^2 gyl = variance due to genotype x year x locationl ly = locations x year, e = variance for error, rly = replication x location x year. The variance components were calculated from Table 2 where l, y, r, g, and e are total number of locations, years, replication , genotypic variance, and error variance respectively. By substituting the values of variance components in the above formula, the variance of a genotype mean can be predicted for any combination of years, locations, and rep lications. The smaller the values of variance of a genotype mean, the more precise will be the estimates of genotype mean.

Results and Discussion

Results of combined analysis of variance pooled over all locations and years (Table 2) indicated that all main effects (*viz,* years, locationss and varieties) were highly significant (P<0.01). The cultivar x year and cultivar x location effects were also significant (P<0.01). The cultivar means averaged over the four locations and four years ranged from a low of 14.26 tons/ha for oat cultivar fulgrain to a high of 17.90 t/ha for S-81.

Estimates of variance for genotypes and genotype x environment interactions are presented in Table-2. The impor-

TABLE 1. ANNUAL WINTER RAINFALL, TEMPERATURE AND SOIL TYPES OF FOUR LOCATIONS.

	AARI Faisalabad	ARI Sariab (Quetta)	ARI Tandojam	NARC Islamabad
Av.winter rainfall	160 mm	250 mm	100 mm	360 mm
Temperature	10-25°	2-17°	15-28°	5-20°
Soil types	Clay loam	Calcareous loamy	Silty and sandy loam	Calcareous silt loam

TABLE 2. FORM OF ANALYSIS OF VARIANCE AND MEAN SQUARE EXPECTATION FOR FORAGE YIELD OF OAT.

Source	D.F.		Mean squares
Years	3		259.55**
Locations	3		8262.23**
Yr x Loc	9		220.69**
Reps (Yr x Loc)	16		1.29
Genotypes	12	M5	32.25**
Gen x Loc	36	M4	19.77**
Gen x Yr	36	M3	16.23**
Gen x Yr x Loc	108	M2	14.47**
Error	192	M1	0.81

**, Significant at 1 percent level. Yr, Loc, Reps, and Gen are numbers of years, locations, replications, and genotype respectively.

tance of various components is indicated by their relative magnitude. The genotype x year x location variance component had the greatest magnitude and therefore, was the most important among all the estimates. The large second order interaction is common in studies related to genotype x environment interactions. Estimate of the genotype x year interaction effect was larger than the estimates of genotype and genotype x location interaction effect. The presence of significant genotype x location interaction indicated that the 13 oats cultivars responded differently for forage yield during 4 years of testing at the individual locations. Similarly, significant genotype x year interaction suggested a differential genotypic response from year to year when averaged over different locations. All the oat genotypes included in this study were selections from different germplasm sources. They were selected under the environment typical of Punjab Province, Pakistan, and were not supposed to have wide range adoptation. Therefore, the significant genotype x environment interaction obtained were not unexpected. The climatic conditions rarely repeat yearly patterns, and different locations exhibit a wide variation in acidity, rainfall, temperature, drainage, soil type, and fertility; therefore these interactions of genotypes x environments appear to arise from specific conditions existing in a particular environment. The variation in environmental conditions necessitates to modify the evaluation procedures through the restriction of evaluation materials to a subset of original location and increase in number of years to test the materials. Also, the magnitude of genotype x environment interaction can be reduced by grouping similar locations into a group.

Table 3. Estimate of Variance Components and Method of Determination for Forage Yield.

Source of variance	Method of determination	Green fodder yield (t/ha)
Genotypes	M5+M2-M3-M4 / Rep x Loc x Yr	0.34
Gen x Loc	M4-M2 / Rep x Yr	0.22
Gen x Yr	M3-M2 / Rep x Loc	0.66
Gen x Yr x Loc	M2-M1 / Rep	6.83**
Error	M1	0.81

**.Significant at 0.1 level. Gen, Loc. Yr and Rep are numbers of genotypes, locations, years and replications respectively.

The genotype x year x location interaction effect was also highly significantly ($P<0.01$) and the variance component pertinent to this source of variation was about six times larger than the genotype x year and genotype x location components (Table 3). It was evident from these results that there some additional environmental factors that were not accounted for either by location or year groupings. Wide variation in soil types, soil fertility, temperature, prevalence of complex of insects, pests, diseases, and rainfall distrubution are known to exist among the four locations selected for the study. These could bave contributed to the large genotype x location x year interaction effect. Horner and Frey [1] developed the concept in oat that cultivar x location interaction effects could help to develop and criteria to decide whether a large area such as a privince should be divided into smaller sub-areas to increase the precision with which varietal evaluation and performance trials are conducted.

It is advisable that an adequate samples of environments may be included in the study by planting genotypes at a number of locations and years. Because an increase in number of years is time consuming, calculation of variance was made by keeping years = 2 and 4, different number of replications and locations were substituted in the formula. Results of these calculations are presented in Table 4. A few points are very interesting and worthy of consideration in Table 4. By keeping the number of replications and years constant, the expected variance of variety mean decreases as the number of locations increases. Thus a critical point will be reached beyond which an increase in the number of locations will provide only a small gain in precision of the experiment. As with the given number of years, it is clear that if very few locations are

Table 4. Expected Variance of a Variety Means (Vx) for Various Assumed Numbers of Replications and Locations Per Test.

No. of replication	No. of years: 2 — No of locations: 2	4	6	8	10	12	No. of years: 4 — No. of location: 2	4	6	8	10	12
2	2.25	1.29	0.97	0.81	0.71	0.65	1.18	0.67	0.50	0.42	0.37	0.34
3	2.22	1.27	0.96	0.80	0.70	0.64	1.16	0.67	0.50	0.42	0.37	0.34
4	2.20	1.26	0.96	0.79	0.70	0.64	1.16	0.66	0.50	0.42	0.37	0.33
5	2.19	1.26	0.95	0.79	0.70	0.64	1.15	0.66	0.50	0.42	0.36	0.33
6	2.18	1.26	0.95	0.79	0.70	0.64	1.15	0.66	0.50	0.41	0.36	0.33

included in the experiment, increase results in a considerable decrease in the expected variance of a variety mean. However, with an increase in number of locations, the effect of number of year to reduce the expected variance of a variety mean becomes less important. It is clear from Table 4 that regardless of the number of locations and years used in the experiments, the assumed values of replications have very minor effect in modifying the expected variance of a variety mean. Table 4 shown only a general trend indicating the relative effects of number of years, locations, and replication. It is evident from Table 4 that increase in number of test locations is more effective in decreasing the expected variance of a variety mean than an increase in the number of years which in trun is more effective than an increase in number of replications.

In this study data were recorded from four experimental stations located in three provinces of Pakistan. We propose that the three provinces be devided into sub-areas on the basis of variation in rainfall, temperature, soil fertility, and soil types in order to minimize genotype x environment interaction effects, and thereby increase the efficiencies of forage oat evaluation programmes.

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