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Genotype×Environment Interaction for Resistance to Purple Blotch (*Alternaria porri* L. (Ellis) Cif.) in Onion (*Allium cepa* L.) in Nigeria

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Abstract: Five onion cultivars were crossed in a diallel and their progenies evaluated at Sokoto and Talata Mafara, during the 2004/2005 and 2005/2006 seasons. Thirty milliliter of 10^{-1} cfu of spore suspension of *Alternaria porri* was poured into each plot. Combined analysis indicated that location, recorded highly significant mean squares ($p<0.01$) for disease incidence, fresh and cured bulb yields. Genotype recorded highly significant ($p<0.01$) mean squares for all characters. Genotype×location interactions recorded highly significant ($p<0.01$) mean squares for disease incidence and severity and fresh and cured bulb yields.

Key words: Genotype, environment, resistance, purple blotch,

INTRODUCTION

Onion (*Allium cepa* L.) belongs to the genus *Allium* (Messiaen, 1994). In comparison with other fresh vegetables, onions are relatively high in food value (Hussaini *et al*., 2000). They contain a phytochemical quercetin, which is effective in reducing the risk of cardiovascular disease, an anticancer and has promise as an antioxidant (Smith, 2003). On a worldwide basis, onion ranks as one of the five most important fresh market vegetable crops (Cramer, 2000). In Nigeria the crop is second only to tomatoes in importance among the vegetables and is maiuly grown for its bulbs (Hussaini *et al*., 2000). Onion is produced world wide, in 2004, 56.80, 4.26 and 1.06 million metric tonnes were produced of dry bulb for the world, Africa and West Africa and 615,000 metric tonnes for Nigeria (FAOSTAT, 2004). Similarly, in 2004, 3.09 million hectares were cultivated with onion the world over. In Africa, West Africa and Nigeria 280,059 ha, 61,160 ha and 41,000 ha, respectively were cultivated with onions in 2004 (FAOSTAT, 2004). Global average yield of onion in 2004 has been estimated at 18.3 t ha^{-1}, with 15.21 t ha^{-1} for Africa, 15.187 t ha^{-1} for West Africa and 15 t ha^{-1} for Nigeria (FAOSTAT, 2004).

According to Green (1969, 1972) low onion production in Nigeria is as a result of pests and disease infestation and of the traditional methods employed in onion production by the local farmers (Kadams, 1983). Wet season trials at the Institute for Agricultural Research (IAR), Samaru, Zaria, found that low yields were associated with attack by leaf pathogens especially *Alternaria porri*.

Purple blotch of onion caused by *A. porri* is an important disease of onion worldwide except in very cool production areas (Awad *et al*., 1978; Everts and Lacy, 1990a; Brar *et al*., 1990; Aveling *et al*., 1993, 1994; Chaput, 1995, Cramer, 2000; Schwartz *et al*., 2005). It is especially troublesome in warm and humid environments (Suheri and Price, 2000). The fungus attacks both leaves and flower stalks (Bock, 1964), reducing foliar production by 62-92% (Suheri and Price, 2001). The disease can cause a yield loss of 30% (Everts and Lacy, 1990b) and 100% of the seed crop when the

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weather favours it (Daljeet *et al*., 1992; Schwartz, 2004). Purple blotch disease of onion is so important as a disease complex that nutrition (Awad *et al*., 1978), cultural practices (Arboleya *et al*., 2003), environmental conditions (Everts and Lacy, 1990a; Suheri and Price, 2000, 2001) and prevalence of other disease factors (Brar *et al*., 1990) all contribute to resistance or susceptibility to the disease, thereby making it more difficult to control. The most reliable measure of control of the disease so far is through crop rotation and use of resistant varieties (Delahaut and Stevenson, 2004; Latin and Helms, 2001) or good cultural practices (Schwartz, 2004; Allen, 2005). The use of resistant varieties is not ouly suitable to low input farming, but also reduces the consequence of chemical sprays on non target organisms and on the environment (Thomas and Waage, 1996).

Genotype×environment interaction (G×E) is of notable importance in the development and evaluation of new varieties and an ideal variety is one that combines high yield with stability of performance (Ado and Ishiyaku, 1999). Russell and Stuber (1985) studied genotype×photoperiod and genotype×temperature interactions in maize using a six parent diallel mating design. They recorded significant differences between the genotypes with respect to environmental variation. McCallnm *et al*. (2001) in New Zealand reported that firm storage onion types produced from areas in higher latitudes (intermediate to long-day) are highly pungent and have high dry matter with soluble sugars, in contrast to onions selected from lower altitude (short-day varieties) which generally have lower pungency, lower dry matter and relatively more simple sugars that impart sweetness (fructose and sucrose). They also reported that both genotype and environment affected days to 50% tops down, days to maturity, pungency and soluble solids under New Zealand conditions. They also indicated that pyruvic acid content is strongly influenced by environmental variation and the method of extraction.

The objective of our study was to determine the genotype×environment interactions of resistance to purple blotch disease in onion under northern Nigerian conditions. Our aim was to obtain information, which will serve as a guide in the breeding of resistant cultivars for this region, where onion is an economically important crop. For this purpose we conducted a diallel cross between five shortday cultivars choosen for their diverse responses to purple blotch and then assessed their performance in field trials at two locations over two seasons.

MATERIALS AND METHODS

Seeds of five onion varieties Red Creole (H), Kaharda (I), Konmassa (A), Sokoto Local (G) and Ori (E) were crossed in a complete diallel mating to generate diversity for resistance to purple blotch disease (Table 1) during the 2003/2004 onion growing season (October 2003-May 2004). Sokoto local was also chosen because it is the local standard cultivar. Seeds of the varieties were raised in a nursery where the soil was thoroughly mixed with farmyard manure at the rate of 5.5 t ha^{-1} (NAERLS, 1993). The seedlings were allowed to grow for a period of forty- nine days and later transplanted into plastic pots of 1458 cm^3. The seedlings were allowed to grow to form bulbs. Bulbs generated were then cut across to encourage flowering and planted into plastic pots of the same dimension for growth up to flowering. At flowering diallel cross was made among the five varieties in all possible combinations giving rise to twenty-five progenies, including the crosses, selfs and the reciprocals.

The twenty five progenies and their parents were evaluated over two onion growing seasons (2004/2005 and 2005/2006) at two locations: Sokoto (Kwalkwalwa village; latitude 13° 06' 28 N and longitude 05° 12' 46 E) in Sokoto State and T/Mafara (latitude 12° 13' 18 N and longitude 06° 05' 05 E and altitude 1150 m) in Zamfara State of Nigeria. In each field trial the genotypes were laid out in a Randomised Complete Block Design (RCBD) and replicated three times at each location and growing season. The total farm area was 333 m^2 per season, with a plot size of 1.8×1.5 m of sunken beds. The genotypes were:

Table 1: Description of the five onion varieties used in the study

Variety	Source	Description	Purple blotch resistance rating
Red Creole	Seminis Vegetable Seeds. Los Angeles, California, USA.	Red, long storage, flattened, globe shape. Long season to maturity and low yields, short day 'Asgrow' brand. Selected for growing in the hot and humid environment of Louisiana, USA	Highly resistant
Kaharda	Office National des Am'enagements Hydro-agricoles (ONAHA), Konni, Niger Republic.	Light red, late maturing.	Resistant
Koumassa	Institut National de Recherches Agronomiques du Niger (INRAN), Maradi, Niger Republic	Red, late maturing.	Moderately resistant
Sokoto local	Farmers collections from Kwalkwalawa village, Wamakko Local Government Area, Sokoto State	Brown, flat globe and late maturing	Susceptible
Ori	International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Sadore, Niamey, Niger Republic. Bred by Hazera, Israel.	Texas Grano type, early maturing, matures very nniformly, light brown skin, short storage.	Highly susceptible

1 = A, 2 = E, 3 = G, 4 = I, 5 = H, 6 = A×E, 7 = A×G, 8 = A×I, 9 = A×H, 10 = A×A, 11 = E×A, 12 = E×G, 13 = E×I, 14 = E×H, 15 = E×E, 16 = G×A, 17 = G×E, 18 = G×I, 19 = G×H, 20 = G×G, 21 = I×A, 22 = I×E, 23 = I×G, 24 = I×H, 25 = I×I, 26 = H×A, 27 = H×E, 28 = H×G, 29 = H×I and 30 = H×H

Seeds for all the experiments were sown on 15th of October of each year in a nursery. Farmyard manure at the rate of 5.5 t ha^{-1} (NAERLS, 1993) was thoroughly incorporated into the soil of the nursery beds, thereafter sunken beds of 2×1 m dimensions were made. The soil was made into fine tilth after removing large stones and stumps and watered then left for two days. Seeds of the genotypes for evaluation were separately broadcast into the sunken beds and mulched with millet stalks and irrigated. One week after germination the mulch materials were removed from the beds. The seedlings were thereafter watered (irrigated) in the evenings at two days interval initially and later at five days interval until the time of transplanting.

Transplanting of the seedlings was carried out forty nine days after sowing (7 WAS). The seedlings were removed from the seedbeds after watering to moisten the soil. At the field sites the seedlings were transplanted at a spacing of 30 cm between rows and 15 cm within rows. Each plot consisted of six rows of ten plants per row, the genotypes being evaluated were planted in the two middle rows of each plot and the other four rows were planted with a guard row onion variety (Aleiro).

No fertilizer was applied to the fields because according to Awad *et al*. (1978) application of nitrogen to onion plants increases susceptibility to purple blotch disease due to the production of succulent leaves, while addition of potassium and calcium super phosphate improves resistance to purple blotch.

Soil tests were conducted at both locations and for both seasons. The results of the soil analysis indicate that the soil at Sokoto is sandy loam while at Talata Mafara the soil is loamy sand.

The inoculation of the field was carried out at two weeks after transplanting allowing the seedlings to overcome the transplanting shock and also close enough to 10 WAS when the varieties used in the study were at the 5-7 leaf stage. This is in accordance with Arboleya *et al*. (2003) who reported that plants should be inoculated at 5-7 leaf stage. Thirty milliliters of 10^{-1} cfu of the spore suspension of *Alternaria porri* was poured in the centre of each plot immediately after irrigation.

The first three irrigations of the fields after transplanting were carried out every four days. Thereafter irrigations were maintained at 5 day interval up to harvest. At Sokoto irrigation was by

flooding method using water pump, while at Talata Mafara irrigation was by flooding using the gravity method, using water from canals constructed by the Bakolori irrigation project.

No sprays of any kind were carried out since the genotypes were being evaluated for fungal infection. Three weeding regimes were carried out during each season at each location. The first weeding was carried at 10 WAS, the second at 14 WAS and the last at 19 WAS. Weeding was done manually by hoeing.

Harvesting was carried out when more than 50% of the tops were down for all the materials. The crops were carefully harvested using hoes to bring the bulbs to the surface of the soil, while the upper parts of the plants were cut with knives and sickles to separate the bulbs from the tops level with the neck. The harvested bulbs were spread on the floor in a ventilated room and allowed to dry for 10 days.

Data on fresh bulb yield (kg ha^{-1}), cured bulb yield (kg ha^{-1}), average bulb weight (g) were determined by weighing ten bulbs. Bulb diameter was determined using a vernier calliper for ten bulbs and days to maturity was recorded when 50% tops were down for each plot. Number of leaves/plant were counted at maturity. Disease incidence (%) and disease severity were assessed fortnightly. Disease incidence was determined according to Tarr (1981):

$$\text{Disease incidence (\%)} = \frac{\text{No. of diseased plants}}{\text{Total No. of plants}} \times 100$$

Diseased plants were plants that had sunken spots on leaves, which later eularged to become purple with a yellow halo and elongated destroying the leaf tissue and eventually causing the bulb to rot. Disease severity was determined for each plot on the basis of standard procedures recommended by the International Plant Genetic Resource Institute, Rome, Italy. The rating was in the following order: 1 = Highly resistant, 2 = Resistant, 3 = Moderately resistant, 4 = Susceptible and 5 = Highly susceptible (IPGRI *et al*., 2001).

Data of the experiments were statistically analysed using the Statistical Analysis Systems (SAS, 1996) computer package. The statistical model used for the combined analysis over seasons and locations was a mixed model given by Obi (1986) as:

$$Y_{ijkl} = \mu + G_i + L_j + S_k + RL + (GL)_{ij} + (GS)_{ik} + (LS)_{jk} + (GLS)_{ijk} + e_{ijkl}$$

Where:

Y_{ijkl} = The observation on i^{th} genotype in j^{th} envirounment in k^{th} replication
μ = The general mean
G_i = The effect of genotypes
L_j = The effect of location
S_k = The effect of season
RL = The effect of replication within season and location
$(GL)_{ij}$ = The effect of genotype×location interaction
$(GS)_{ik}$ = The effect of genotype×season interaction
$(LS)_{jk}$ = The effect of location×season interaction
$(GLS)_{ijk}$ = The effect of genotype×location×season interaction
e_{ijkl} = The error effect associated with $ijkl^{th}$ observation

The components of variance were estimated from the mean squares for each character by using the observed mean squares, thus with reference to Table 2 and 3.

Table 2: Form of Analysis of variance (ANOVA) table for single experiment (one season one location)

Source of variations	df	MS	EMS	F-test
Replication	r-1			
Genotypes	g-1	MS_2	$\delta^2e + r\delta^2g$	MS_2/MS_1
Error	(r-1) (g-1)	MS_1	δ^2e	

r = No. of replications, g = No. of genotypes, δ^2e = Error variance, δ^2g = Total genetic variances among the genotypes MS subscript: The observed mean squares of the subscript effect

$$\delta^2_e = MS_1 \quad \text{and} \quad \delta^2_g = \frac{MS_2 - MS_1}{r}$$

$$\delta^2_{ph} = \frac{MS_2 - MS_1}{r} + MS_1$$

RESULTS AND DISCUSSION

Combined analysis of variance for the two seasons at Sokoto indicated highly significant genotypic mean squares for all the characters (Table 4). The season and genotype x season interaction were not significant for all the characters. At Talata Mafara, the genotypic variances were highly significant for all the characters while the genotype x season interaction indicated significant mean squares for bulb weight ouly (Table 5).

Highly significant mean squares were observed for the genotypes for all the traits during the 2004/2005 season across the locations (Table 6). The analysis also indicated highly significant mean squares for replications within location for disease incidence and disease severity and significant mean squares for fresh bulb yield. Fresh and cured bulb yields recorded highly significant mean squares for location, while disease incidence recorded significant mean squares for location during the season.

During the 2005/2006 season, however, the combined analysis across locations indicated highly significant genotypic mean squares for all the traits. Location effect was highly significant for fresh and cured bulb yields, while disease incidence recorded significant mean squares (Table 7). The genotype×location interactions were not significant for all the traits measured.

The performance of the genotypes and their parents across seasons and locations (Table 8), indicated cultivars Koumassa, Kaharda and Red Creole having lower mean disease incidence and higher mean fresh and cured bulb yields than their respective grand means. Crosses A×H, A×I, H×A, H×I, I×A and I×H recorded lower mean disease incidence than their grand mean, while crosses A×H, A×I, H×A, H×I, I×A and I×H recorded greater mean fresh and cured bulb yields than their grand mean.

Combined analysis across seasons and locations indicated highly significant ($p = 0.01$) mean squares for the genotypes for all the characters (Table 9). Highly significant mean squares were also recorded for the genotype×location for disease incidence and disease severity and fresh and cured bulb yields. Similarly, highly significant location effects were recorded for disease incidence and fresh and cured bulb yields. The genotype×season×location interactions were, however, not significant for all the traits. Similarly the seasonal effects, the season by location and the genotype by season interactions were not significant for all the traits.

According to Lamkey (2006), plant breeders evaluate germplasm in envirouments to identify genotypes that exhibit optimal adaptation to the needs of society, the demands of nature and the desires of the market place. The combined analysis of the experiments indicated significant variation among the parents and the crosses evaluated for all the traits under study (Table 9). Both superior and inferior genotypes exist in the population, with respect to the characters under consideration. This therefore suggests that selection for these traits during breeding programmes is possible.

The combined analysis of variance across seasons and locations also indicate that location, genotypes and genotype×location interaction were the sources of variation that accounted for the variability observed with respect to disease incidence (Table 9). This suggests that the two locations

Table 3: Form of combined Analysis of variance (ANOVA) across seasons and locations

Source of variations	df	MS	EMS
Seasons	y-1		
Locations	l-1		
Reps within seasons and locations	yl(r-1)		
Seasons×locations	(y-1) (l-1)		
Genotypes	g-1	MS_5	$\delta^2e + r\delta^2gly + ry\delta^2gl + rl\delta^2gy + rly\delta^2g$
Genotype×season	(g-1) (y-1)	MS_4	$\delta^2e + r\delta^2gly + rl\delta^2gy$
Genotype×location	(g-1) (l-1)	MS_3	$\delta^2e + r\delta^2gly + ry\delta^2gl$
Genotype×season×location	(g-1) (y-1) (l-1)	MS_2	$\delta^2e + r\delta^2gly$
Error	yl (g-1) (r-1)	MS_1	δ^2e
Total	rgly-1		

Table 4: Combined analysis of variance for eight onion characters grown at Sokoto during the 2004/2005 and 2005/2006 seasons

Source of variation	df	Disease incidence	Disease severity	Fresh bulb yield	Cured bulb yield	Bulb diameter	Bulb weight	Days to maturity	No. of leaves/plant
Season	1	8.890	0.00	2412.0	36637.10	0.38	1.36	158.67	0.45
Reps within season	4	28.190	0.38	84438.0	137499.50	0.42	48.01	793.28	2.08
Genotype	29	3476.610**	9.61**	49543099.0**	33106140.66**	8.63**	996.15**	9319.84**	25.74**
Genotype× Season	29	3.716	0.15	5769.0	35115.50	0.46	54.09	500.78	0.88
Error	116	19.430	0.21	245021.0	174308.00	1.20	237.46	1183.70	2.16

*: Significant at 5%, **: Significant at 1% levels of significance

Table 5: Combined analysis of variance for eight onion characters grown at Talata Mafara during the 2004/2005 and 2005/2006 seasons

Source of variation	df	Disease incidence	Disease severity	Fresh bulb yield	Cured bulb yield	Bulb diameter	Bulb weight	Days to maturity	No. of leaves/plant
Season	1	3.47	0.50	16415.0	11388.0	1.62	43.89	1467.76	1.61
Reps within season	4	58.89*	0.58**	825748.0*	336344.0*	0.07	88.26	2.19	0.33
Genotype	29	3448.99**	10.13**	52753771.0**	34525457.0**	9.27**	1001.35**	10216.18**	30.28**
Genotype× Season	29	4.05	0.12	16794.0	22782.0	0.92	251.82*	795.57	1.01
Error	116	17.22	0.16	260589.0	124874.0	0.94	151.79	871.74	1.33

*: Significant at 5%, **: Significant at 1% levels of significance

Table 6: Combined analysis of variance for eight onion characters grown at Sokoto and Talata Mafara during 2004/2005 season

Source of variation	df	Disease incidence	Disease severity	Fresh bulb yield	Cured bulb yield	Bulb diameter	Bulb weight	Days to maturity	No. of leaves/plant
Location	1	86.81*	0.22	2457528.0**	1763741.30**	0.29	442.55	330.76	2.94
Reps within location	4	74.86**	0.69**	621139.0*	298867.30	0.39	62.97	630.69	1.99
Genotype	29	3498.32**	9.76**	50961290.0**	34085954.00**	10.11**	1110.13**	11340.15**	29.77**
Genotype ×Loc	29	32.49	0.34	353873.0	159785.80	0.80	156.02	846.57	1.81
Error	116	19.69	0.19	247376.0	167724.00	1.13	182.78	1016.32	1.78

*: Significant at 5%, **: Significant at 1% levels of significance

Table 7: Combined analysis of variance for eight onion characters grown at Sokoto and Talata Mafara during 2005/2006 season

Source of variation	df	Disease incidence	Disease severity	Fresh bulb yield	Cured bulb yield	Bulb diameter	Bulb weight	Days to maturity	No. of leaves/plant
Location	1	108.89*	0.006	2216058.0**	1060765.0**	0.012	175.43	56.67	1.25
Reps within loc	4	12.22	0.260	389047.0	174976.5	0.090	73.29	164.78	0.41
Genotype	29	3383.03**	9.700**	50700289.0**	33289511.4**	7.680**	948.91**	8135.00**	25.05**
Genotype× Location	29	19.52	0.200	303981.0	154243.7	0.690	88.35	510.65	1.26
Error	116	16.96	0.170	258234.0	131457.7	1.010	206.46	1039.11	1.72

*: Significant at 5%, **: Significant at 1% levels of significance

Table 8: Mean performance of onion crosses and parents inoculated with *A. porri* grown at Sokoto and Talata Mafara during 2004/2005 and 2005/2006 seasons

Crosses/ parents	Disease incidence (%)	Fresh bulb yield (kg ha^{-1})	Cured bulb yield (kg ha^{-1})	Bulb diameter (cm)	Bulb weight (g)	Days to maturity	No. of leaves/plant
A×E	92.50	880	794	5.49	58.73	170.00	6.33
A×G	75.83	2465	1627	5.02	46.08	178.20	7.17
A×H	61.25	4137	2606	5.32	47.88	172.80	8.00
A×I	67.92	3655	2449	5.23	51.36	167.80	8.08
G×A	75.00	2489	1643	5.11	44.91	175.30	6.67
E×A	93.75	816	780	5.50	58.12	156.00	7.08
E×G	94.17	795	705	4.32	51.25	129.20	5.08
E×H	83.33	1709	1538	5.24	47.06	173.50	6.83
E×I	87.92	1451	1088	5.29	54.36	172.30	6.33
H×E	82.92	1701	1531	5.16	46.18	174.30	6.33
G×E	92.50	848	718	5.49	53.24	176.90	5.33
G×H	82.92	1450	943	5.39	40.98	176.90	8.17
G×I	79.58	1875	1181	5.12	42.50	172.00	7.33
H×A	61.25	4120	2595	5.23	47.79	184.00	8.33
I×G	78.75	1958	1234	5.13	42.11	170.70	7.17
H×G	82.08	1461	954	4.99	36.95	176.00	6.83
H×I	18.33	9777	8311	5.43	53.87	172.70	9.67
I×A	67.50	3642	2440	5.28	49.77	167.30	6.92
I×E	88.33	1488	1117	5.32	58.43	168.80	6.33
I×H*	18.33	9787	8319	5.43	54.03	174.70	9.17
A	65.00	3853	2697	5.11	49.90	172.30	7.67
E	96.67	389	365	2.26	22.39	70.60	1.50
G	81.25	1768	1149	5.35	43.38	178.60	8.33
H	23.33	8959	8063	5.48	52.59	180.30	8.83
I	35.83	7717	5263	5.33	54.00	172.10	9.00
Grand mean	71.24	3187	2364	4.87	45.49	160.20	6.76
$DMRT_{\alpha=0.05}$	3.48	405.40	309.60	0.82	11.09	25.55	1.06

Table 9: Combined analysis of variance of onion genotypes inoculated with *A. porri* at Sokoto and Talata Mafara for two seasons

Source of variations	df	Disease incidence	Disease severity	Fresh bulb yield	Cured bulb yield
Season	1	8.33	0.003	10015.00	6726.00
Location	1	176.33**	0.003	5578455.00**	2857135.00**
Season×location	1	0.00	0.083	9383.00	6417.00
Reps within season×location	8	56.17**	0.54**	451066.00*	193370.00
Genotype	24	6086.23**	18.37**	89853129.00**	57488267.00**
Genotype×season	24	2.95	0.12	11274.00	15992.00
Genotype×location	24	41.79**	0.42**	533088.00**	251613.00**
Genotype×season×location	24	5.03	0.18	11152.00	14204.00
Error	192	15.80	0.17	212002.00	102083.00

Source of variations	df	Bulb diameter	Bulb weight	Days to maturity	No. of leaves/plant
Season	1	1.29	12.83	863.60	1.61
Location	1	0.69	1014.02*	255.76	7.05*
Season×location	1	0.06	32.37	106.80	0.05
Reps within season×location	8	0.34	47.28	636.99	1.37
Genotype	24	17.24**	1992.05**	18635.42**	45.49**
Genotype×season	24	0.33	151.14	269.85	0.52
Genotype×location	24	0.35	51.78	310.06	1.40
Genotype×season×location	24	1.18	213.55	1123.16	1.66
Error	192	0.88	184.44	833.91	1.69

*: Significant at 5%, **: Significant at 1% levels of significance

differed in disease incidence score for the genotypes. The differences between the locations in environmental conditions most especially during the harvest months of March and April (Table 10) are the likely reason for the location effect. The highly significant genotype×location interaction for disease incidence indicate disease incidence among the genotypes vary with location. In other words, the ranking of the genotypes for the character vary with location. According to

Table 10: Meteorological data for harvest period at Sokoto and Talata Mafara during 2004/2005 and 2005/2006 seasons

	Sokoto			Talata Mafara		
Month	Min. T° (°C)	Max. T° (°C)	Relative humidity (%)	Min. T° (°C)	Max. T° (°C)	Relative humidity (%)
2004/2005 season						
March 2005	22.10	37.80	12.50	36.50	30.78	80.14
April 2005	22.90	39.70	16.80	53.50	51.34	77.00
May 2005	23.30	36.20	36.60	35.83	34.00	85.30
June 2005	21.08	31.70	48.50			
2005/2006 season						
Feb 2006	18.51	34.82	55.75	35.80	34.20	94.00
March 2006	19.00	36.90	43.34	37.50	21.30	90.70
April 2006	22.10	39.10	42.60	35.80	32.90	88.30

Source: Sokoto Energy Research Center, Sokoto and Institute for Agricultural Research meteorological station Talata Mafara

Everts and Lacy (1990b) the disease can cause a yield loss of 30%, while Daljeet *et al*. (1992) and Schwartz (2004) reported yield loss of 100% of the seed crop when the weather favours the disease. The severity of purple blotch disease is greatly influenced by location (environment), nutrition (Awad *et al*., 1978), cultural practices (Arboleya *et al*., 2003), environmental conditions (Everts and Lacy, 1990a; Suheri and Price, 2000, 2001) and prevalence of other disease factors (Brar *et al*., 1990), all of which contribute to resistance or susceptibility to the disease. The influence of the environment on the development of purple blotch has been reported by several authors. Green (1972), reported that wet season trials of onions at IAR Samaru, Nigeria were associated with low yields which was attributed to attack by leaf pathogens especially *Alternaria porri* (Ell). In our trials disease severity was significant for genotype and genotype×location interactions suggesting that the pattern of location effect on disease severity was similar to that of disease incidence as expected. For both traits, the magnitude of the genotypic variance is higher than the first order interaction variance. The second order interactions were not significant for any of the measured traits. Breeders and farmers have long known that the best variety in one season in a sample of ten similar locations might not be the best in another season or when averaged across several seasons at the same locations (Lamkey, 2006). Uuless therefore G×E is dealt with effectively, the potential genetic gains of plant breeding programmes will not be realized and delivered to the market place. According to Van Eeuwijk (2006), while experimental error can complicate characterization of genotypic performance, it can be reduced by experimental design and/or analytical methodologies. Within - location replication is also useful, since it allows separation of G×E from experimental error, thereby enabling better characterization of G×E. Unfortunately, G×E interaction can not be reduced or mitigated by design or analysis methods because G×E is an inherent attribute of the given genotypes in the given environment.

The combined analysis also indicated that fresh and cured bulb yields were highly significantly influenced by location, genotypes and genotype×location interaction. Breeding for resistance to purple blotch and for fresh and cured bulb yields should take cognizance of these factors. Breeding for fresh and cured bulb yields in onions should therefore be location specific. Similar conclusions were reported by other workers (Jones and Mann, 1963; Purseglove, 1972; Bednarz and Olarewaju, 1986). According to Van Eeuwijk (2006), in the absence of G×E and with experimental error at reasonably low levels, average phenotypic performance across environments provides a good representation of genotypic performance. Consequently, relative performance of genotypes can be determined from differences in these phenotypic performances. However, in the presence of significant G×E interaction, relative genotypic performance can ouly be characterized for specific environments.

Location effects were also significant for bulb weight and nnmber of leaves/plant while genotypic differences for the traits were highly significant. The result therefore suggests that location and genotypes are two important factors to consider when selecting for bulb weight and nnmber of

leaves/plant in onions. The results indicate a need for location specificity when breeding for fresh and cured bulb yields in onion. Bulb diameter and days to maturity did not show any significant differences for seasons, locations and their interactions suggesting that the determining factor when selecting for these traits is the genotype. McCallum *et al*. (2001), however, in New Zealand, working on locally-adapted longer-day onions, reported that both genotypes and enviroument affect days to 50% tops down (days to maturity), pungency and soluble solids. Differences between their findings and ours may be connected with the fact that all of our onion cultivars were short-day and relatively well-adapted to our locations. Also, the cultural practices for the two sets of experiments may not have been the same during the cultivation of the crop.

The variations observed between different research groups may be counected with environmental variations. G×E interaction can be used to describe differential genotypic response to various geographic locations in a given year. There is also a temporal component to G×E, since the same geographic location will have a different enviroument in different years and at different times of the year (e.g., effects of planting date and growing season). In order to deal explicitly with both the spatial and the temporal aspects of environment, the G×E is separated into genotype×location, genotype×season and genotype×season×location (Van Eeuwijk, 2006).

CONCLUSIONS

From our research we conclude that genetic diversity in short-day onions with respect to resistance to purple blotch disease exists and that breeding for resistant cultivars is therefore possible. Location, genotype and genotype×location interactions were shown to influence disease incidence, fresh and cured bulb yields all of which are characters important in resistance to the disease. In future West African breeding programmes for resistance to purple blotch disease therefore these factors should be considered.

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