have a maximum waxy scores (1) (unpublished). The glossy trait with diverse resistance might well be incorporated in the Mexican breeding lines.

Genetic diversity

The genotypic diversity among glossy lines for agronomic traits and shootfly resistance has been estimated following Mahalnobis D^2 (Table 9.27). The genotypes having different glossy scores were grouped into 2 minimum groups.

Table 9.27 Genetic diversity of glossy lines for agronomic and shoot fly resistance traits. [PE = Plants with eggs; DH = Plants with deadhearts]

Characters	Group A	Group B
Days to flower	(S1, S2)	(S3 , S4)
Plant height, cm	(S1, S2, S3, S4)	
Panicle length, cm	(S1, S2)	(S3, S4)
100 seed weight, g	(S1, S2, S4)	(S3)
PE (%)	(S1, S2)	(S3, S4)
DH (%)	(S1, S2)	(S3, S4)

Among agronomic traits days to flower and panicle length have similar pattern of clustering, i.e. high and medium glossy groups (S1, S2) form one cluster (A) and low glossy group (S3, S4) form another clusture (B). Similar patterns were observed in shootfly resistance parameters, PE and DH%. In the case of plant height and 100 seed weight, the clustering pattern showed no relationship with level of glossiness.

Grain and fodder improvement

Means and correlations of some agronomic characters of importance for grain and fodder improvement, including days to flowering, plant height, panicle length, panicle breadth and 100-seed weight were evaluated for 513 sorghum genotypes classified acoording to glossy score classes (Table 9.28). Glossy genotypes were generally tall and late in in flowering. Genotypes with days to flowering less than 75 days and plant height more than 250 cm have been considered for grain and fodder improvement. The results indicate that in all the cases, the desirable expressions of the traits for grain yield improvement (earliness, short stature, large panicle and high 100-seed weight) had an inverse relationship with intensity of glossiness.

The correlations among the agronomic traits in high glossy and low glossy lines based on the selection for grain, fodder and grain/fodder are shown in Table 9.29. These values indicate that in the glossy group selected for grain yield, days to 50 % flowering had a negative association with panicle length and breadth, but a possitive association with 100 seed weight. None of the associations were significant in less glossy groups. In the case of genotypes selected for fodder yield, plant height was significantly correlated with panicle length in high glossy groups but none of the associations were found to be significant in high and low glossy score groups. In the lines selected for fodder and grain yield, panicle length showed significant

Table 9.28 Mean values of agronomic traits within each glossy score for different selections during Rabi season in India. [* P=0.05, ** P=0.01]. Figures in parenthesis indicate the number of genotypes in each class.

Class	DF[1]	PH[1]	PANL[1]	PANB[1]	100SDW[1]
a) Overall					
Score 1 (267)	77.76	216.76	13.46	6.69	2.22
Score 2 (208)	76.30	212.71	4.18	6.62	3.29
Score 3 (38)	72.08	210.14	16.43	7.26	3.53
Overall (513)	76.78	214.65	13.96	6.65	3.27
b) Selection for grain yield potential					
Score 1 (111)	68.88	212.14	14.21	6.75	3.20
Score 2 (101)	69.03	208.16	14.94	6.81	3.29
Score 3 (23)	67.52	206.60	17.50	7.63	3.49
Overall (235)	68.80	209.86	14.86	6.87	3.27
c) Selection for fodder yield improvement					
Score 1 (52)	78.57	263.52	14.81	7.12	3.25
Score 2 (39)	78.15	267.07	16.21	6.92	3.42
Score 3 (7)	74.33	268.89	18.28	7.78	3.64
Overall (98)	78.04	265.38	16.66	7.10	3.25
d) Selection for forage and grain yield improvement					
Score 1 (31)	76.45	265.45	17.39	8.33	3.30
Score 2 (24)	78.69	270.58	19.79	7.58	3.59
Score 3 (4)	71.17	265.83	22.92	9.25	3.98
Overall (59)	76.86	267.54	18.86	8.11	3.48

[1] DF : Days to 50 % flowering; PH : Plant height (cm); PANL : Panicle length (cm); PANB : Panicle breadth (cm); 100SDW : 100 seed weight (g).

negative correlation with days to flowering and significant positive relationship with plant height. Therefore, with an increase in days to flowering, panicle length and panicle breadth got smaller. Early flowering is desirable for better panicle length and breadth, which are considered responsible for grain improvement. Plant height, which is considered as a desirable trait for fodder improvement, showed positive association with other grain yield contributing traits like panicle length, panicle breadth and 100 seed weight. This indicates that taller plants with high glossiness may be desirable for fodder improvement.

These results reveal that glossiness is not associated with deleterious traits, but rather showed significant correlations among the desirable agronomic traits like plant height, days to flowering and panicle length, both for grain and fodder improvement. Therefore, the genotypes with high glossy scores could be explored for genetic improvement for grain and fodder yields.

Genotypes with superior agronomic traits for their potential use by breeders for grain yield improvement (with < 70 days to 50% flowering) are: IS 4334 (59 days to 50% flowering), IS 4522 (56), IS 4523 (52), IS 4776 (59), IS 5139 (57), IS [illegible]5 (47), IS 8311 (52), IS 8655 (57), IS 17815 (59), IS 18499 (52), IS 18571 (59),

Table 9.29 Correlations among agronomic traits within each glossy scores selected for potential uses. [* P=0.05, ** P=0.01]

Character	Correlations among agronomic traits: High glossy (score 1 & 2)	Low glossy (score 3 & 4)
a) **Selected for grain**		
DF vs PH	0.03	0.23
vs PANL	-0.34 **	-0.24
vs PANB	-0.17	-0.28
vs 100 SDW	0.27	0.13
b) **Selected for fodder**		
PH vs DF	0.21	0.41
vs PANL	0.62 **	0.07
vs PANB	0.18	-0.70
vs 100 SDW	0.15	0.06
c) **Selected for fodder & grain**		
DF vs PH	0.02	0.13
vs PANL	-0.39 *	-0.54
vs PANB	-0.09	-0.31
vs 100 SDW	0.26	0.33
PH vs DF	0.20	0.13
vs PANL	0.56 **	0.43
vs PANB	0.23	-0.72
vs 100 SDW	0.11	0.24

and IS 18627 (59).

Some promising germplasm lines for breeding for forage improvement are (plant height > 250 cm): IS 1054, IS 1560, IS 1560, IS 2268, IS 2282, IS 4578, IS 4632, IS 4675, IS 5047, IS 5172, IS 22196, IS 6566, IS 7891, IS 16534, IS 16088, IS 16528*, IS 2185*, IS 166611*, and IS 166640* (* promising forage yielders).

For dual purpose, forage and grain (plant height > 250 cm and days to 50% flowering < 70): IS 1054, IS 1560, IS 2185, IS 2268, IS 4578, IS 4632, IS 5172, IS 5553, IS 6566, IS 7891, IS 16088, IS 16528, IS 16611, IS 16614, IS 16614, 16640, and IS 22196 are suggested.

Similar studies were undertaken for Kharif season data on high and low glossy lines (Table 9.30). The mean values reveal that low glossy groups had agronomic desirability as observed in Rabi season data. The correlations between days to flowering and plant height were significant among all the genotypes and among the subgroups selected for grain and forage in high and low glossy lines. Glossy sorghum lines could be favourably utilized for fodder improvement. Since glossy traits are also associated with resistance traits, the genotypes of high glossy class can be selected and tested in semiarid situations of the world especially in India and Africa to assess their genetic potential for fodder and grain production.

ble 9.30 Mean values and correlations among some agronomic traits of ssy sorghum genotypes in different score classes during Kharif season. P=0.05, ** P=0.01]

lasses	OVERALL Mean DF[1]	OVERALL Mean PH[1]	OVERALL r	GRAIN Mean DF	GRAIN Mean PH	GRAIN r	FORAGE Mean DF	FORAGE Mean PH	FORAGE r
verall	89	341	0.75 **	70	286	0.62 **	90	349	0.78
ore 1	89	346	0.81 **	71	298	0.53 **	89	348	0.81**
ore 2	89	335	0.70 **	69	277	0.61 **	91	349	0.76*
ore 3	86	332	0.77 **	66	264	0.68 **	90	352	0.74**

DF = days to flowering, PH = plant height, cm.

wth analysis and productivity of some glossy sorghum genotypes under gated and rainfed situation In Mexico

Fifteen glossy sorghum genotypes (IS 5604, IS 1034, IS 4663, IS 18390, IS 2205, 5484, IS 8315, IS 5642, IS 1096, IS 8977, IS 5587, IS 4776, IS 5622, IS 5567, IS 46) were evaluated for growth analysis and fodder productivity under irrigated d rainfed situations in Nuevo Leon, Mexico.

owth pattern: Plant height= growth was slow under nonirrigated conditions, but er irrigation plants grew faster. Leaf area= under irrigation and nonirrigation, af area showed first a gradual and then sharp rise up to 76 days, but under nfed condition, growth was reduced. Net assimilation rate (NAR)= NAR was her under irrigation than rainfed conditions. Under the rainfed situation, 5567 showed maximum NAR and IS 8315 the minimum. Under the irrigated nditions, IS 8315 showed maximum NAR and IS 4776 the minimum. The geno- es showed sharp increment in NAR from 61 to 76 days under irrigation. Under rainfed situation, IS 5567, IS 5604 and IS 5642 showed similar growth pattern n the irrigated situation. Under irrigation, leaf number, leaf dry matter and m dry matter did not show significant differences (P= 0.05) at 31, 46, 61 and days, but plant height showed differences. These variables showed significant ference among stages (P=0.05) and interaction, genotype x stage were also nificant (P = 0.05). Under the rainfed situation, leaf number, leaf dry dry weight d plant height showed significant differences among genotypes (P= 0.05), but m dry matter and leaf area did not show differences. These variables showed ferences among stages and genotypes x stages interaction. Dry matter partition MP)= DMP showed large differences among genotypes under both irrigated d nonirrigated conditions. Under nonirrigated conditions, IS 5604, IS 1034, IS 46, IS 4663, IS 1096, IS 8977, IS 4776 and IS 5622 showed similarity in DMP) % in stem, 20 % in leaf and 10% in panicle), but for IS 18390, IS 2205, IS 84 and IS 5567 DMP in the stem was 70 %, and for IS 5484 only 40 %. IS 8315 owed maximum dry matter proportion in stem (70%). In IS 18390 and IS 2205, y mater in leaves were 44 and 43 % respectively, with the minimum in IS 5567 %). The proportion of dry matter in the panicle was maximum in IS 5484 0%) and minimum in IS 5642. Under the rainfed situation, the genotype beha vior was similar in majority of the genotypes. IS 18390, IS 2205, IS 5484 and IS 5567 showed different behaviour. Fodder yield (Table 9.31)= under rainfed conditions IS 5587, IS 5604, IS 5484 and IS 4776 are recommended for forrage and grain production in semiarid India and Mexico.

Table 9.31 Average fodder yield (dry matter, tons/ha) of some glossy sorghum lines in Nuevo León, México.

Genotype	Fodder yield (dry matter, ton/ha) Rainfed	Irrigated
IS 5604	16.20	15.16
IS 1034	12.81	13.95
IS 2146	10.44	8.15
IS 4663	13.75	12.36
IS 18390	13.84	12.48
IS 2205	13.02	18.00
IS 5484	16.17	12.54
IS 5642	12.78	12.92
IS 5587	18.49	19.26
IS 8315	11.37	13.11
IS 1096	11.43	12.14
IS 5567	13.18	13.36
IS 4776	14.00	14.30

Utilization of glossy lines in sorghum crop improvement

Two easily identifiable traits, the trichomes and glossiness are highly inheritable, with simple inheritance and additive in their effects in the shootfly incidence (Maiti and Bidinger, 1979; Maiti and Gibson, 1981; Gibson and Maiti, 1981). Adopting this technique Agrawal (1984, personal communication) made good progress in breeding for shootfly resistance since it is an easily identifiable trait during seedling stage, the early generations segregating materials can be evaluated based on this trait and at the later stage can be tested under shootfly pressure to verify their reaction.

In general, glossy lines showed higher recovery percentage after release of stress than the nonglossy plants. Some nonglossy lines showed good recovery. Therefore, the resistance mechanism cannot be ascribed solely to the glossy character, other factors, as yet unidenfied, seem to play a role in drought resistance. Breeders at ICRISAT have started to backcross to the agronomically elite materials, the traits, trichomes and glossy leaves, as many of the elite lines lacked the resistance traits.

The glossy lines were generally poor agronomically, but some lines have been identified as having good agronomic traits: IS 4663, IS 4405, IS 5642, IS 3962, IS 4776, IS 5567, IS 4473, IS 2394, IS 1096, IS 2280, IS 5621, IS 5067, IS 6942, IS 4661, IS 2314 and IS 1054 (Rodíguez-Sandoval, 1991).

NCLUSIONS

Sorghum genotypes could be easily distinguished into 2 distinct morphological pes, glossy and nonglossy lines at the seedling stage. The glossy lines vary widely seedling morphology, intensity of glossiness and waxy surface. About 85% of e glossy lines show presence of nonglandular microscopic hairs, trichomes on e surface. Some sorghum lines from germplasm with trichomes and glossy traits wed a higher level of resistance to shootfly. Some lines are resistant to stem rer also. Both trichomes and glossy trait are linked and have a large repercus- n on shootfly resistance, thereby improving the prospects for development of ltivars with increased resistance. Glossy lines also showed variability in biochemi- l traits which need to be related to their resistance mechanisms to various resses.

Some glossy lines have better tolerance to seedling drought, but there were me lines falling in the susceptible group. Most of the glossy lines have been entified as land races belonging to the race Durra and predominantly distributed central India. Some of them are exotic in origin and show diversity in geograph- l distribution. Though many of the glossy lines are poor in agronomic traits, me lines with desirable agronomy were identified. These lines could be recom- ended for forrage and grain improvement in the semiarid tropics.

Insects, pests and the lack of adequate moisture supply are the major barriers improving sorghum crop production in SAT areas. For a long time, physiologists d breeders have been testing for simple characteristics which reliably predict ought resistance. At the same time, physiologists in collaboration with breeders d entomologists are working together to identify simple morphological traits ated to insect and drought resistance. The use of trichome and glossy trait oves to be the most effective and reliable selection criteria in the breeding for ootfly maintenance, and probably drought resistance. The variability in several ochemical traits like HCN, chlorophyll (a, b, and total), water use efficiency and ax contents among glossy sorghums could be correlated with resistance mecha- sm to different stress factors.

ROBABLE PLANT TYPE CONCEPT IN SORGHUM

The term 'plant type' include a set of morphological characteristics contributing higher yield in sorghum. Since sorghum is grown both under optimal and boptimal conditions in the semiarid tropics and termperate regions, concepts better plant type in a particular situation differ with region. Plant type concept uld be investigated for sorghum with some modifications. The following morpho- gical characteristics in sorghum deserve particular attention:

Short stiff culms

For efficient utilization of soil moisture in rainfed conditions, short and stiff lms of 1-2 m height are desirable. A short sorghum plant may make more dging and be stalk root resistant. A strong stem with intensity of mechanical sue-sclerenchyma offers resistance to lodging stalk rot and is also insect resistant.

Stout and juicy stem may prove susceptible to insect and disease. For this, only a part of the internode should be covered with leaf sheath. A single culm is desirable for high yield.

2. Erect leaves

Erect leaves with a stiff midrib forming an acute angle with the stem permit deeper penetration and even distribution of light which may result in increased photosynthesis. A waxy coating on the leaf surface may reduce transpiration in dryland agriculture. Glossy leaves with thick cuticles and dense trichomes may be associated with insect and drought resistance.

3. Root system

A profuse root with a number of deep roots is ideal in rainfed agriculture. Long seminal roots are desirable for the initial establishment of seedlings. Presence of pericyclic lignification may be associated with drought resistance and resistance to root rot. A higher number of nodal roots may be disadvantageous to the plant. A smaller number of nodal roots arising from basal nodes are required for mechanical support as well as absorption of soil moisture during the grainfilling period. Under optimum soil moisture, the roots may need to be distributed at shallower depth.

4. Panicle

A panicle with large number of intermediate or bold grains and good exsertion is desirable for high yield. A large and compact panicle may provide favorable environments for insect and disease attack in the tropics. Therefore, a loose panicle with long primary branches and a large number of grains is ideal in these environments. Large seeds should be exposed, and up to 75% of them should be covered with glume. Bold seed associated with white grain is desirable for quality with good stand establishment.

GENERAL COMMENTS

Traditional yield advances in different crops have been achieved by the combined efforts of management specialists, plant pathologists, entomologists and plant breeders. To accelerate this progress, biochemists and plant physiologists have recently joined the team. A through knowledge of basic plant sciences and an understanding of plant growth and crop production would provide a key to identify the physiological, morphological and architectural components of the germplasm with superior yield. For this, the proper exploitation of the rich sorghum germplasm resource and cataloguing the resources to make them available all over the world is a basic prerequisite to maximize the crop yields.

The next step is identification of resistance traits and their proper utilisation in breeding to keep up the yield potential. This knowledge in turn can be used to increase yield potential.

As discussed in earlier chapters, the formulation of simple techniques for identification of sorghum lines with different resistance was attempted. Some sorghum germplasm showing multiple resistances have been identified. Breeders may attempt to transfer the resistance genes to elite lines by adopting a suitable

hod and incorporating resistant traits in early generations. Progenies of crosses ween resistant and susceptible elite lines could be tested at early germination out taking recourse to any plant protection measures and selected progenies s advanced may have the potential to accumulate resistant genes. These nced lines could be adaptable to a wide range of environments and resist ught, pests and diseases.

A superior genotype with multiple resistance should be selected, developed and ed under different environments to exert selection pressure. Then the breeder d incorporate multiple resistance into elite lines by establishing the corresding genetic inheritance.

Most of the advances in crop production in the advanced countries have heen ieved from empirical breeding and management research. Research efforts e been directed to develop highyielding crop varieties under good crop manment condition, but very little fundamental research on plant responses to vorable environments and the mechanism of adaptation under adverse dition has been done. Some basic questions remain. What are the traits respone to tolerate drought, salinity, low phosphate, heat, etc. What is the biochemical s for these tolerances and how are they genetically controlled ?