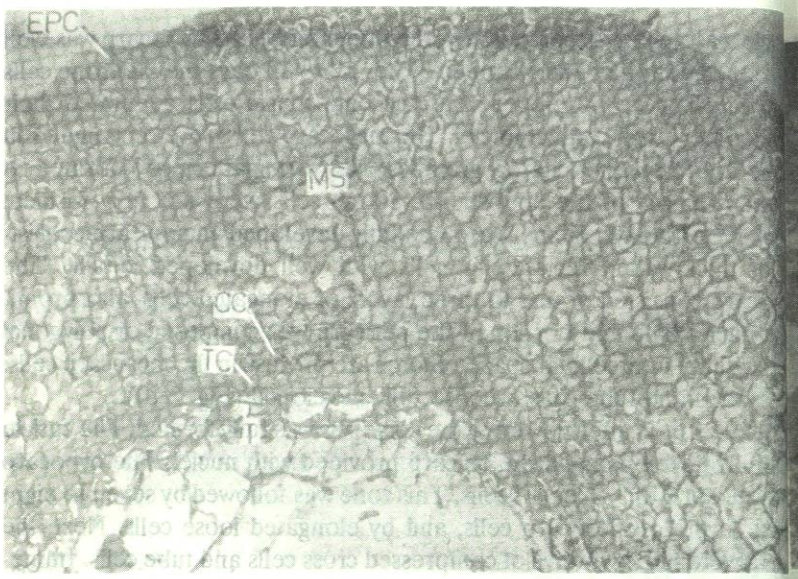

Figure 2.10 Transverse section of a caryopside (12-13 days after anthesi showing a well developed epicarp (EP), mesocarp (MS), cross cells (CC tube cells (TC) and testa (T).

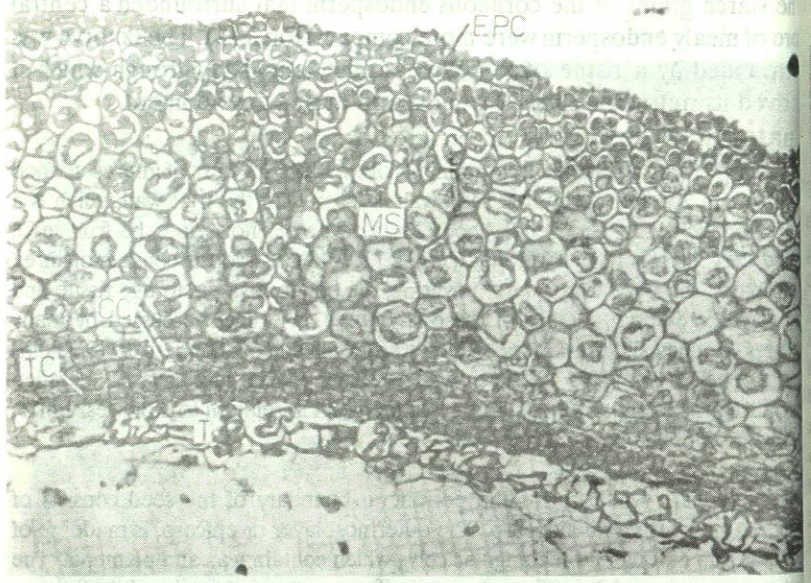

Figure 2.11 Transverse section of a well developed caryopside showin the epicarp (EP), mesocarp (MS), cross cells (CC), tube cells (TC) an testa (T).

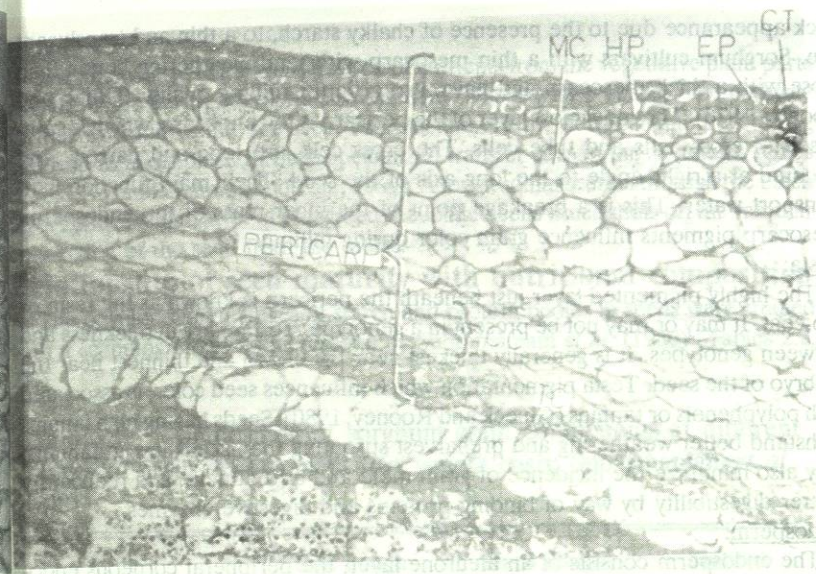

Figure 2.12 Transverse section of a mature caryopside showing cuticle (C), epicarp (EP), hypocarp (HP), mesocarp (MS), cross cells (CC), and tube cells (TC).

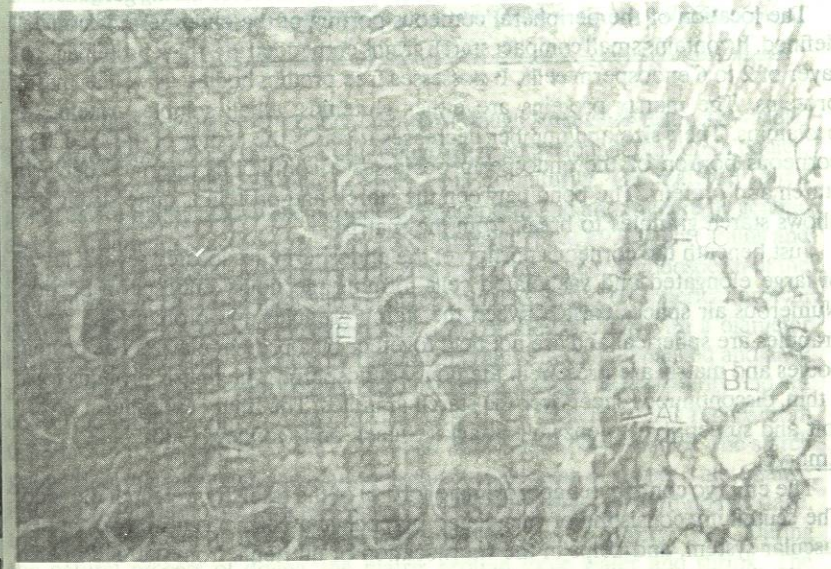

Figure 2.13 Transverse section through the hilar region showing endosperm (E), black layer (BL), cross cells (CC), and aleurone layer (AL).

thick appearance due to the presence of chalky starch, to a thin and translucent one. Sorghum cultivars with a thin mesocarp withstand weathering better than those with a thick mesocarp and have also a better milling quality (Gluek and Rooney, 1976). The innermost layer of the pericarp is the endocarp, which is composed of cross cells and tube cells. The cross cells are long and narrow, and oriented at a right angle to the long axis of the seed. Their main function is to transport water. This is a breakage point of the inner mass of the endosperm. Mesocarp pigments influence grain color during milling.

Testa:

The highly pigmented layer just beneath the pericarp is known as the testa or sub-coat. It may or may not be present in a genotype. Testas vary in thickness and between genotypes. It is generally thickest near the crown and thinnest near the embryo of the seed. Testa pigmentation which influences seed color, is associated with polyphenols or tannins (Glueck and Rooney, 1980). Seeds having high tannins withstand better weathering and preharvest sprouting than seeds low in tannins; they also minimize the incidence of grain mold and bird attacks, and reduce dry matter digestibility by way of binding proteins and digestive enzymes.

Endosperm:

The endosperm consists of an aleurone layer, the peripheral corneous endosperm and the central floury portion. The aleurone layer is located beneath the pericarp, which consists of a single layer of narrow rectangular cells. The cells of aleurone layer under high magnification shows spherical bodies which contain large amounts of proteins, oils, minerals, water soluble vitamins and autolytic enzymes (Glueck and Rooney, 1980). They do not contain starch grains and play a great role in autolysis, as well as in the mobilization of food reserves during germination.

The location of the peripheral corneous portion of the endosperm is not well defined. It contains small compact starch grains embedded in a thick proteinaceous layer of 2 to 6 endosperm cells. It possesses free protein bodies, as well as matrix proteins. The matrix proteins are either glutenins, alkali soluble proteins, or prolamins. Their size and number decreases towards the center of the seed. The corneous portion of the endosperm possesses a continuous interface between starch and protein. The bond between the starch and protein is quite strong and allows starch granules to break from the matrix.

Just beneath the corneous portion of the endosperm are located several layers of large elongated and vacuolated cells forming the floury endosperm portion. Numerous air spaces exist between the starch granules and protein. The starch granules are spherical and are not held together by a protein matrix. The protein bodies and matrix are present in the floury endosperm. The matrix proteins form a thin, discontinuous sheet over the starch granules. The floury endosperm is very soft and susceptible to enzymic attack (Glueck and Rooney, 1980).

Embryo:

The embryo contributes approximately 10 % of the total dry weight of the seed. The scutellum, consisting of vacuolated perenchyma cells, has a well developed vascular system, and helps in the translocation of nutrients from the endosperm into the developing roots and leaf tissues of the embryonic axis during germination.

Hilum:

The hilum helps in the translocation of nutrients from the vegetative plant parts into the ovule during caryopsis development. This way also become the pathway for microorganisms into the seed. Translocation of the nutrients into developing endosperm takes place through specialized transfer cells in the scutellum (Giles *et al.*, 1975, and Gunning and Pate, 1969). A longitudinal section through the black layer zone reveals a layer of elongated vacuolated cells which shuts off the vascular connection of the seed from the rachis.

Relationship of seed maturity with nutritional composition

The developmental stages of starch and protein bodies in seeds were studied with a scanning electron microscope by Subramaniam *et al.* (1980) (Tables 2.2, 2.3).

Table 2.2 Composition of sorghum grain components at different stages of grain development (dry weight basis; Subramaniam *et al.*, 1981).

	Soft dough	Hard dough	Mature
Dry matter	59.69	75.59	89.22
Ether extract	2.86	3.33	2.86
Crude fiber	2.79	1.89	1.76
Crude protein	11.71	11.94	11.96
Total ash	1.79	1.40	1.42
Nitrogen free extract	81.03	81.50	82.00
Starch	67.33	69.94	71.34

The aleurone cells at soft dough and hard dough stages are distinctly visible. The peripheral endosperm at the soft dough stage show abundant protein bodies, and a starch grain size between 11 and 12 μm at maturity. The matured starch granules are tightly held in the peripheral endosperm and are affected by genetic and environmental factors (Sanders, 1955; Maxson *et al.*, 1971). The grains and protein bodies increase in thickness and size with time. The soft endosperm of the immature seed has large intercellular spaces. Sparse small and spherical protein bodies are also present in endosperm cells at soft dough stage with a diameter between 9 and 10 μm. At maturity the starch grains are loosely packed and have a diameter between 15 and 19 μm. They decline in number with maturity and are converted into the hard endosperm. The size of the protein bodies ranges from 0.75 and 1.00 μm, and these are embedded in the endosperm matrix. The starch granules at the middough stage are polygonal or globular in shape. They change into the polyhedral type progressively as the seed matures. At hard dough stage, the endosperm is not tightly packed and, in some cases, it is very loose. During the natural process of drying, the matrix protein loose water and shrink. The peripheral endosperm beam becomes hard and assumes a translucent appearance during drying. The intercellular spaces are filled with protein bodies and thick

matrix proteins at physiological maturity.

Table 2.3 Aminoacid composition of sorghum grain (Subramanian *et al.*, 1981).

Amino acid	CONCENTRATION IN PROTEIN Soft dough	Hard dough	Mature
Lysine	1.98	1.79	1.90
Histidine	1.95	2.02	1.96
Arginine	3.00	3.06	3.17
Aspartic acid	7.76	7.49	7.42
Threonine	3.10	3.12	3.13
Serine	4.94	4.81	5.09
Glutamic acid	22.79	22.94	22.50
Proline	8.89	8.81	8.42
Glycine	3.38	3.51	3.63
Alanine	9.77	10.03	9.57
Cystine	0.25	0.54	0.45
Valine	3.53	3.52	3.72
Methionine	1.64	1.63	1.60
Isoleucine	2.62	2.63	2.69
Leucine	13.13	13.21	13.14
Tyrosine	3.46	3.61	3.77
Phenylalanine	4.77	4.88	4.90

Crude protein, crude fibre and ash content decrease with maturity of seed the nitrogen free extract and starch content increase. The number and size of protein bodies increase progressively as maturity advances. The glutamic acid leucine contents increase slightly with maturity while an inverse relationship found for lysine and the total protein content (Table 2.2).

Grain dry weight accumulation and contents of soluble starch, protein, fat ash were investigated by Subramanian *et al.*, (1983) in developing grains of sorghum cultivars. High lysine Ethiopian lines showed relatively low starch, high protein content at various stages of maturation, which suggests a poss mechanism of protein accumulation. Fat content showed a tendency to incre up to 28 days after flowering (Subramanian *et al.*, 1983).

PHYSICAL AND PHYSIOLOGICAL CHARACTERISTI

A considerable diversity of physical and physiological characteristics exist sorghum, and the general trends are briefly discussed here (Table 2.4).

Seed hardness:

Seed of different cultivars vary from very hard to soft; some are hard to bre

nd some are easily breakable. Seed hardness can be measured with the help of grain hardness tester. It measures the weight in kg required to break the seed. rain hardness may be closely associated with the quality of the seed, as well as e weathering quality.

Table 2.4 Different seed characteristics (40 sorghum genotypes).

	Minimum	Maximum
Seed weight (30 seeds, g)	1.17	1.70
Seed length (mm)	3.22	5.85
Seed breadth (mm)	2.15	5.00
Seed thickness (mm)	1.14	3.45
Corneous rating	1.00	5.00
Grain hardness (kg)	1.66	11.19
Density	0.85	1.52
Total water uptake (6 hrs)	0.05	0.48
Water uptake % (6 hrs)	13.70	47.10
Percentage germination	36.70	63.30
First leaf area (cm)	0.30	2.42
Seedling dry wt (30 seeds, g)	0.05	0.37

Density:

Density is the mass per unit volume of a substance, and is measured by the displacement of distilled water:

Density = (weight of the seeds in grams) / (volume of the seed)

n the case of sorghum the density differs widely in different genotypes within a ange of 0.85 to 1.52.

Water uptake:

Water uptake is the capacity of the seed to absorb water. It is expressed in ercentage over the original seed weight after a definite period of immersion. This nay be related to the cooking quality of the seed. Studies in different cultivars ndicate that water uptake ranges from 13 to 47% (based on dry seed weight and bservations six hours after imbibition).

Variability for different morphological and physiological characteristics

The different morphophysiological characteristics of seed size in sorghum elonging to different taxonomic groups were studied by the author at ICRISAT n India. The genotypes included in this study showed significant differences for ll the characteristics studied indicating that there is enough variability to select or these traits (Table 2.4).

Viability for seed wetting and drying

Sorghum has the capacity to survive germination and emergence, even if the merged plumule and radicle dry up, one the conditions become favorable again.

Genotypic differences were noticed in the stand establishment when subjecte soaking and drying treatments. This is a useful trait for areas where seeds are s dry and the rainfall is sufficient to initiate germination, but inadequate to c emergence. The testing technique involves cycles of wetting and drying for di ent time intervals followed by standard planting and germination in the fie

Soaking seed in water and drying to original seed weight induces faster e gence, more vigorous growth and higher yields. Such treated seeds remain vi if the radicle has not emerged, and may be stored for dry planting (Heydecker Coolbear, 1977; Hegarty, 1977). Scientists at the Dryland Farming Rese Scheme in Botswana noticed significantly greater differences for emergen seeds soaked for 24 hours and dried than in the control seed (unsoaked), and results were consistent.

Considerable differences exist among different species in their germinatio a given level of soil moisture (Bhan, 1970). Manohar and Heydecker (1964) fo that seeds of certain species may germinate even when the soil moisture lev at permanent wilting, therefore, genotypes which have the capacity to germi with lower degree of hydration may stand better chances of germination in sc rainfall areas.

Seeds of cereal crops like *Pennistum typhoides* and *Sorghum vulgare* are be able to germinate at lower levels of water potential than the seeds of leg crops. In the arid and semiarid zones, where rains are uncertain and erratic, showers are often sufficient for germination but not sufficient for emergence high temperatures, soil moisture gets depleted and germinating seedlings dr in the soil (Ramírez and Bejarano, 1973). Watt (1973) reported that some g species can germinate in the soil moisture with tensions of -5 to -10 bar, but the embryo does not develop. Sorghum seed germinated with the availabilit sufficient soil moisture, but this may not be adequate for emergence. Heg (1977) reported that cucurbits and carrot can germinate in dry soil, can sur dehydration and rejuvenate under favorable conditions. Increasing water con in the seed before sowing favors emergence (Lyles and Fanning, 1964); soak and drying treatment affects the viability of sorghum seed (Jowett, 1965).

The author developed techniques at ICRISAT in India and at the Univer of Nuevo León in Mexico, for the evaluation of sorghum cultivars against stress factor. In one study at ICRISAT (Maiti, 1980, unpublished), sorgh genotypes belonging to different taxonomic groups were tested for germinat in Petri dishes in two replications for 20 hours. Subsequently, the germinated se were dried at 40°C in the incubator for two days and then kept at room tempe ture for ten days. These genotypes were studied for their emergence capability sowing them in wooden flats. Significant genotypic differences were noticed emergence; this stress factor can be attacked with stress resistant sorghum ge types.

Effect of soaking treatment on seed viability and seedli vigor

In another study, seeds of 34 sorghum genotypes were soaked in water in P dishes for varying periods ranging from 4 to 28 hours (at 4 hour intervals) a

transferred to an incubator for drying at 35°C for 36 hours. Thereafter, germination tests were carried out to establish the differences among these treatments. Soaking pretreatment up to 20 hours did not have much effect on seed viability. There was a marked decrease in seed viability with increase in soaking beyond 20 hours. It was interesting to note that all the cultivars germinated within 16 hours. The elongated radicles had produced minute hairs by 20 hours of pretreatment, but the seed was viable even after the radicles and plumules were fully dried. After 28 hours of pretreatment, more than 10 % of the seed germinated even after the long radicles and plumules were dried (Fig. 2.14).

The effect of the soaking treatments on seedling vigor was studied at ICRISAT. In this study, the seedling weight was measured after a five day growth in Petri dish culture and a marked decrease was noticed in seedling dry weight (Fig. 2.15). In another study, a direct correspondence was observed between soaking time and increase mold infestation (Fig. 2.16).

In México, the technique was further modified (Maiti *et al.*, 1983a). Seeds were soaked in water for different periods (4, 8, 12, 16 and 20 hours) in Petri dishes followed by drying in an incubator at 35°C for seven days. Thereafter, the treated seeds were sown in soil and the percentage of emergence and dry weight of seedlings at 15 days was measured. Significant variance was observed between genotypes and treatments. Increase of emergence percentage and seedling dry weight was noticed in the four and eight hours soaking treatments. Henceforth, a gradual decline was observed as the hours of presoaking increased and the minimum was reached between 16 and 20 hrs. At ICRISAT the author found that some genotypes did not lose their viability even after 36 hours of soaking pretreat-

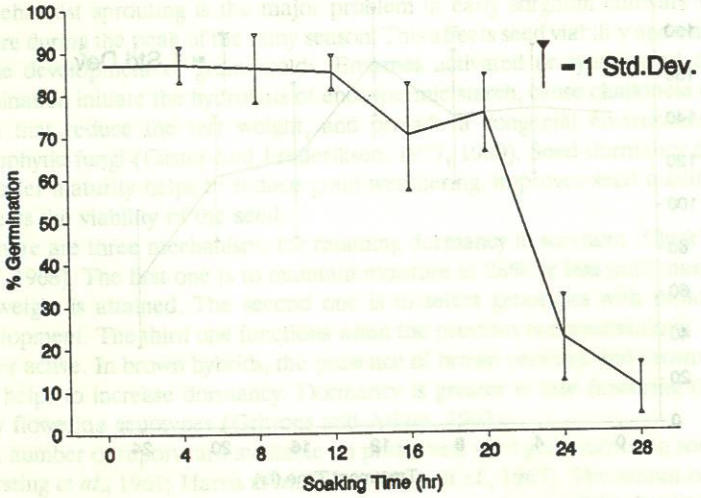

Figure 2.14 Germination % after different soaking times and drying for 24 hr at 40°C.

ment followed by drying for 10 days at 35°C in an incubator (Maiti, unpublishe The use of these lines needs to be tested in dry sowing conditions, and sorghum germplasm may be screened for this trait.

In Mexico, Moreno-Limón (1988) demonstrated that some genotypes did lose their viability even after 40 hrs of presoaking and drying at 35°C for 15 da Also, genotype resistance seems to be linked to a specific protein which is abs in susceptible strains (Maiti, 1989, unpublished). Genotypes selected for this re tance traits could be recommended for dry sowing under rainfed situations semiarid regions such as in temporal agriculture in Mexico.

Associations among different morphophysiological characteristics

The relationships among different seed characteristics may be used to ident certain useful traits of seedling growth. Seed size (weight) shows significant posit association with seed dimensions (r = 0.8), total water uptake (r = 0.8), a seedling dry weight (r = 0.8). The total water uptake at six hours is significant a is positively correlated with seed dimensions and seedling dry weight (r = 0. but water uptake (%) is negatively associated with seed size and dimensions. Se dimensions (thickness, length and breadth) and scutellar length are well associate Grain hardness is significant and positively correlated with seed length, bread and length of the scutellum, and also with corneousness. First leaf area is positiv associated with the seedling dry weight, which is well associated with seed siz

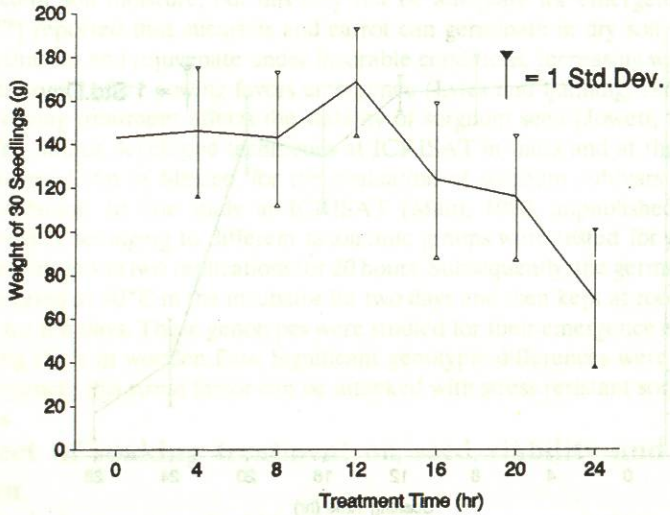

Figure 2.15 Effect of the duration of the soaking treatment on the vigor of the seedlings.

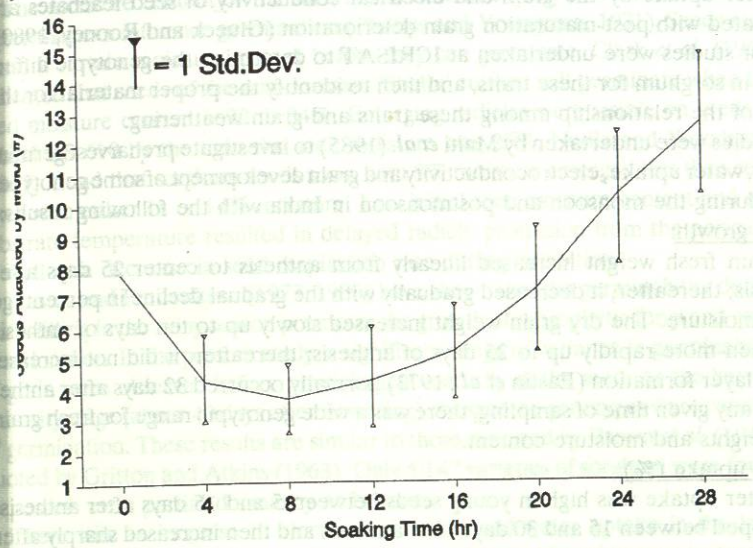

Figure 2.16 Effect of the soaking treatment on mold infestation of the seedlings.

GERMINABILITY AND SOME ASPECTS OF PRE-HARVEST AND POST-HARVEST

Preharvest sprouting is the major problem in early sorghum cultivars which mature during the peak of the rainy season. This affects seed viability and enhances the development of grain molds. Enzymes activated or synthesized during germination initiate the hydrolysis of endospermic starch, cause chalkiness of the grain that reduce the test weight, and provide a congenial environment for saprophytic fungi (Castor and Frederiksen, 1977, 1980). Seed dormancy during and after maturity helps to reduce grain weathering, improves seed quality and protects the viability of the seed.

There are three mechanisms for retaining dormancy in sorghum (Clark *et al.*, 1967, 1968). The first one is to maintain moisture at 28% or less until maximum dry weight is attained. The second one is to select genotypes with rapid seed development. The third one functions when the previous two mechanisms are no longer active. In brown hybrids, the presence of brown pericarp and brown teeth also helps to increase dormancy. Dormancy is greater in late flowering than in early flowering genotypes (Grittons and Atkins, 1963).

A number of reports are available on preharvest seed germination in sorghum (Kersting *et al.*, 1961; Harris *et al.*, 1962; Clark *et al.*, 1967). The tannin content of the testa is associated with reduced preharvest germination (Harris and Burns, 1970) and reduced preharvest grain molding (Harris and Burns, 1973). The rate

of water uptake by the grain and electrical conductivity of seed leachates associated with post-maturation grain deterioration (Glueck and Rooney, 19 Similar studies were undertaken at ICRISAT to determine the genotypic di ences in sorghum for these traits, and then to identify the proper material for study of the relationship among these traits and grain weathering.

Studies were undertaken by Maiti *et al.* (1985) to investigate preharvest ger ability, water uptake, electroconductivity and grain development of some genot both during the monsoon and postmonsoon in India with the following resu

Grain growth:

Grain fresh weight increased linearly from anthesis to center 25 days a anthesis; thereafter, it decreased gradually with the gradual decline in percent grain moisture. The dry grain weight increased slowly up to ten days of anth and then more rapidly up to 25 days of anthesis; thereafter, it did not incre Black layer formation (Eastin *et al.*, 1973) normally occurred 32 days after an sis. At any given time of sampling, there was a wide genotypic range for fresh dry weights and moisture content.

Water uptake (%):

Water uptake was high in young seeds between 5 and 15 days after anthe it dropped between 15 and 30 days after anthesis and then increased sharply a physiological maturity. The genotypic variability was small during the period w mean rates were low, but increased significantly by the 40th day; this character may be of significance for resistance to weathering and prevention of germina on the panicle when they exposed to rains (Castor and Frederiksen, 1977).

Electroconductivity:

The electroconductivity of the seed leachates did not change five days a anthesis near the black layer stage. Thereafter, it increased significantly toge with water uptake. Genotypic variability was considerably greater for conduct than for water uptake during the whole sampling period.

Germination:

Most genotypes began germination between 20 and 30 days after anthe however, actual percentage of seeds germinated during this period varied con erably among different genotypes. After 30 days of anthesis, when all except lines had initiated germination, germination ranged from 3 to 100%. After 40 d of anthesis the minimum germination was 76 %, indicating that at the time maturity (about 10% moisture) no significant dormancy existed in any of the lin A number of genotypes had less than 50% germination at 35 days after anth (IS 6127, IS 6205, IS 6204, IS 9374, IS 3921 and IS 165). The advantage of trait under field conditions during the rainy season is not yet fully establishe

Germination initiated among the lines tested in the post-monsoon was sim to that during the rains, however, germination began earlier, as 5% of the initiated germination at 10 days after anthesis, and this went up to 92% at 25 d At physiological maturity, all the lines had initiated germination but nearly 5 lines showed less than 50% germination. Some lines showed less than 1 germination (IS 2074, IS 4310, IS 6131, IS 9333, IS 15021, IS 15709, IS 16201 IS 16657). In all these studies, genotype and genotype X time of sampling w significantly different in all the parameters studied.

The moisture content of the seed at the time of sowing is considered to be a ctor that can influence germination (Phillips and Youngman, 1971). Seeds must tain a certain moisture content before they can germinate. Clark *et al.* (1968) dicated that seeds of the non-dormant 'Shallu' cultivar will germinate when the ed moisture content is 32 to 34%. Emerging radicles were visible on seeds of brid RS 610 by the time the seed moisture was 25%. Nutile and Woodstock 967) found that sorghum seeds sown with 8% moisture emerged less than seed wn with either 11 or 14% moisture. Low initial seed moisture content and low bstrate temperature resulted in delayed radicle protrusion from the pericarp, well as a decrease in seed respiration rate during imbibition.

Castor and Frederiksen (1977, 1980) have shown that the germinability during ain-filling in the rainy season promotes the growth of saprophytic fungi and grain eterioration. In the present study, a significant range of variance in germinability grain were observed before physiological maturity of the seed. At the harvest aturity stage (about 40 days after flowering), most of the genotypes were capable germination. These results are similar to those reported by Brown *et al.* (1948), oted by Gritton and Atkins (1963). Only 5/147 varieties of sorghum were found possess even partial dormancy at harvest.

There was an increase in electroconductivity and water uptake in the later ages of grain development which may be associated with an increase in permeability of the membrane at this stage, either naturally or due to weathering. Entry water into the seed and leaching of materials out of the seed at harvest maturity ere not correlated. Conductivity was less in seed with a corneous endosperm, ough the water uptake appeared to be independent of the corneous rating of e endosperm; conductivity and water uptake appear to be governed by different ctors.

ate of water uptake:

The rate of water uptake was correlated only to seed size, which may reflect e greater surface or volume ratio in smaller seeds. A combined analysis of the ommon variables gave evidence of a seasonal difference in the dormancy of ertain entries. Sampling procedures for germinability, water uptake, etc., should onsider the effects of the environment, the stage of development and the maturity f the seed. Some genotypes which showed some level of dormancy of physiological maturity (30-35 days after anthesis) were identified in both monsoon and post monsoon seasons, i.e. IS 83, IS 188, IS 219, IS 1235, IS 1352, IS 2468, IS 6117 and 6204. It is not know whether this delayed germinability has a measurable effect n grain weathering and the sprouting of the seeds during the rainy season. As ere was no dormancy following physiological maturity, these lines will be affected y rains occurring after maturity. Therefore, instead of looking into these lines in ore detail, a large number of germplasm lines should be screened for entries hich are dormant at late stages of maturity (about 40 days after anthesis) and hich would be more useful to breed for weathering resistance. Therefore, oncerted research efforts should be directed towards developing weather-resistant nes.

In 1990, Maiti and Banerjee (unpublished) showed that grain mold infestation uring grain development severely affected the emergence and seedling vigor of

sorghum genotypes. Large genotypic variability existed for seedling emergen seedling vigor of the sorghum genotypes infested with grain mold. Then concerted efforts should be directed to eliminate the deteriorating effect o mold on sorghum grain quality during the growing period of the crop.

GENERAL COMMENTS

The morphophysiological characteristics of different sorghum genotypes considerable variations in seed size, shape and dimensions, surface orient seed structure, distribution pattern of corneous and floury endosperm, hardness, water uptake, seed viability, first leaf area and seedling dry weigh that all the variations in these characters are statistically significant. An inter fact is that most genotypes do not loose their viability even after presoaki to 40 hours when the radicles and plumules are advanced in growth and then in the incubator for 15 days at 35°C (Moreno-Limón, 1988). Lines select resistance to presoaking and drying could be useful in an area where dry s is practiced. Different seed morphological traits were found to show relation among themselves. They have shown relationships with some of the physiol functions, for example, seed size is related to grain hardness, total water up first leaf area and seedling dry weight. Seed size is negatively correlat percentage water uptake. Grain hardness is positively associated with the con endosperm content; the first leaf is positively correlated to seedling dry w These characteristics could be used as selection criteria for better seedling gr

Sorghum grain attains germinability even before the attainment of physiol maturity. Some start germination at an early stage of grain development, others germinate at a later stage. In order to avoid grain weathering, we s look for genotypes that shows no germinability at major stages of grain ma A number of lines have been selected at ICRISAT which show dormancy stage of physiological maturity. Proper care needs to be taken not to use affected with grain mold causing poor seedling vigor.

3

GERMINATION AND SEEDLING ESTABLISHMENT

TRODUCTION

Germination, emergence and establishment of seedlings are vital to plant velopment. Many morphogenetic changes take place simultaneously before the ablishment of a seedling. These processes involve complex serial, structural and tabolic transitions in possibly adverse situations under erratic environmental nditions. These processes are interrelated, and knowledge of the interactions ong them help in the understanding of the plant's condition at each stage of velopment. The normal process of seedling development is largely controlled environmental factors and influences the development of the adult plant.

Seedling establishment is one of the major obstacles of crop production in the miarid tropics (SAT) (Maiti, 1983, 1986). Despite adequate fertilizer use and igation, the yields are often low in some crops due to poor plant stands, which e a consequence of poor seedling emergence and establishment. Adverse nditions encountered in the SAT countries, like varying planting depths, limited oisture, high soil temperature, soil crushing, etc., affect seedling emergence. erefore, improvement of seedling vigor and testing breeder's lines for crop tablishment traits should be the major considerations in a breeding program. vestigations in this direction have clearly established that which is discussed rein.

Biological and environmental factors associated with screening for improved and establishment in different crop species have been reported by different orkers (Kneebone, 1970; Wright, 1971; McKell, 1972). There has been a good al of work relating seed characteristics with seedling vigor in different crops neebone and Cremer, 1955; Isley, 1958; Kalton *et al.*, 1959; Christie and Kalton, 60; Tossell 1960; Dhindsa and Slinkard, 1963; Lawrence, 1963; Maiti, 1981). neebone (1970) considered the seed size as the most promising selection crite- on available to the breeder to improve seedling vigor. Seed size was related with rly growth and grain yield in barley, and high protein content and seed size were lated to good seedling vigor in wheat (Kaufmann and McFaden, 1963; Kaufmann d Guitard, 1967; Dasgupta and Austerson, 1973; Sterling *et al.*, 1977; Ries and verson, 1973). Seeds with high protein content in wheat produced more vigorous edlings than those with low protein (Welch, 1977; Bullisani and Werner, 1980).

Ching (1973) reported that seed weight, adenosine triphosphate (ATP) and lenosine diphosphate (ADP) contents of the hydrated embryo were good vigor