

Chapter II

Literature Review

Grain sorghum lab performance and field emergence

Field establishment is often lower than that predicted from the standard laboratory germination test. Vanderlip et al. (1973) found values of 79 to 85% for emergence in the field, while the same seedlots in the laboratory showed a germination of 90 to 94%. Working with 13 cultivars during one year in three field trials, Srivastava and Pinnell (1963) evaluated field emergence percentages and found 72% and 92% for field emergence and standard germination tests, respectively. These authors found a highly significant difference among cultivars in field emergence.

Cultivars also performed differently in percent field emergence. Brar and Stewart (1994) found that emergence in the field was influenced significantly by cultivar. The mean for field emergence was 59%, while the same seedlots germinated 91% in a standard laboratory test.

Working with four different temperatures and 26 genotypes, Somman and Peacock (1985) found that both main effects (temperature and genotype) were highly significant in determining emergence. Their technique was successful in predicting a sorghum hybrid's ability to emerge at particular temperatures.

Paliwal (1990) worked with 40 grain sorghum seedlots and found differences in emergence among seedlots. Correlation with field emergence was more evident with cold soil and tetrazolium tests. Wanjari et al. (1992) studied the influence of seed size on germination, field emergence, and vigor in some sorghum genotypes. They found significant differences between standard germination and field emergence percentage.

Ahmed (1977) concluded that high germination percentages in seedlots are not the only criterion to measure seed vigor. He worked with nine sorghum seedlots to test field emergence and found that seven were superior to the others. During 3 years working with eight genotypes, Garcia and Lasa (1991) found differences among seedlots in field emergence.

Camargo and Vaughan (1973) planted low vigor sorghum seeds and observed several physiological and morphological effects such as reduced plant height, delayed panicle exertion, and delayed anthesis. In addition tillering and yield were reduced, and plants were shorter when compared with high vigor seeds. Khosla (1995) planted sorghum seeds at a rate of 120% of the

target plant population following the instructions on the package label. Based on 85% germination, he presumably should have obtained the desired 247,000 plants/ha. Due to poor emergence, however he did not achieve the appropriate final stand. His experience demonstrates the difficulty of predicting field performance based upon laboratory germination data.

Factors affecting sorghum seed emergence

Environmental factors

Temperature

High or low temperatures can affect sorghum germination. According to Kanemasu et al. (1975), the optimum soil temperature for sorghum germination is 23°C. Studies dealing with the effect of various temperatures on emergence have been done in tropical regions, where high soil temperatures can reduce emergence. Kasalu et al. (1993) observed that emergence decreased with increases in soil temperatures above the optimum, and that genotypes behaved differently when under this stress. The same conclusion was reached by Wilson et al. (1982) and Mortloc and Vanderlip (1989).

Cold soil temperatures can also affect germination and emergence (Anda and Pinter, 1994; Harris et al., 1987; and Meyers et al., 1984). Genotypes differ in their germination response to low temperature, but none germinate below 10°C (Anda and Pinter, 1994).

Percentage emergence in the field generally increases with later planting dates, which reflect higher soil temperatures. The highest percentage emergence in one study occurred at about 18°C, but did not increase significantly from 21 to 27°C (Stoffer and Van Riper, 1963). Soil temperatures above 45°C can inhibit the emergence of sorghum seedlings, resulting in poor crop stand (Wilson et al., 1982; Soman and Peacock, 1985). Soman and Peacock (1985) concluded that sorghum genotypes show differences in emergence at 50°C without water stress. According to Ougham and Stoddart (1986), failure of some sorghum lines to germinate at very high temperatures has been shown to be closely correlated with inhibition of embryo protein synthesis in the first hours of imbibition.

Water stress

The ability of sorghum to emerge often depends on its capacity to germinate and grow under limited soil moisture conditions. Bijagare et al. (1994) studied the effect of moisture stress on sorghum seed germination and concluded that germination decreased with increases in levels of water stress; also genotype variations were observed. According to Fawsi and Agboola (1980), the optimum soil moisture requirement for sorghum germination is between 25 to 50% of field capacity. Brar et al. (1992) modeled sorghum seedling establishment using six temperatures

and three matric potentials (-0.03 to -3 MPa). The optimum sorghum emergence (>80%) was obtained at 20°C to 30°C and -0.03 to -0.1 MPa.

Soil crusting

Soil crusting, which can limit sorghum emergence, is dependent on soil aggregation, organic matter, and moisture. A decrease in these components generally increases the density and the crusting of a soil, resulting in decreases in crop emergence (Mali et al., 1977). Soil aggregates affect the seedling's ability to find a low impedance path through which to emerge. Balingar (1975) found that increases in soil aggregate size were correlated with reduced root elongation and emergence.

Root growth and plant vigor can be increased by plowing deeper than 10 cm. Many sorghum emergence problems would be reduced if water loss could be prevented and a loose surface layer maintained. Singh and Das (1987) increased sorghum productivity by 10 to 15% with deep plowing once in 3 years, thus reducing soil crusting. Agrawal et al. (1986) observed that the increases in soil crusting were accompanied by decreases in moisture and that sorghum lines varied in their ability to emerge through the crusted soil. Similar results were found by Soman et al. (1992) using crust-tolerant and crust-susceptible cultivars. The tolerant cultivars had longer and faster growth of the mesocotyl than the susceptible.

Genetic factors

Genotype differences

Sorghum genotypes perform differently in field emergence and in laboratory vigor tests. Several researchers have found differences among genotypes in field emergence, Vanderlip et al. (1973) showed that seedlots differed widely in each variable measured on standard germination and other vigor tests. Baskin et al. (1993) observed that differences existed among 70 sorghum seedlots in germination, and the results were more evident when using the soil cold test than when using the soil heat test.

Genetic variation was observed in the ability of sorghum seedlings to emerge under high soil temperature conditions. Wilson et al. (1982) identified certain lines capable of emergence at soil temperatures of 55°C. Similar results were found by Brar and Swart (1994). Salt tolerance and different osmotic potentials also show significant variations among genotypes. Igartua et al. (1994) concluded that the genotypic difference was an estimate of intrinsic seed vigor.

Seed size

Swanson and Hunter (1936) suggested that the discrepancy between laboratory and field sorghum germination is due to the thickness of a starch layer of the cells located in the seed coat. Seed size is highly influential in determining germination ability and seed vigor of grain sorghum (Maranville and Clegg, 1977). Large and dense seeds had higher percent germination; however, the establishment of seedlings and final stand were not a function of seed size or density. Alessandria (1982) studied factors affecting grain sorghum establishment, and the size of the seeds showed positive correlation with emergence and vigor. Seed weight and field emergence were also discussed by Hyoungh et al. (1974), they concluded that there is a poor relationship between this variable and field performance.

Abdullahi and Vanderlip (1972) and Mortlock and Vanderlip (1989) concluded that establishment and vigor are significantly affected by seed size. Mortlock and Vanderlip (1989) found that the highest germination percentage occurred at 32 to 40°C for medium seeds, while the temperature optimum was 32 to 42°C for large seeds. Also Cortes (1988), working with seven cultivars and lines of sorghum showed that germination increased with seed size. Dighe and Patil (1981) found that small seeds of two sorghum hybrids were inferior to larger seeds in vigor, laboratory germination, and field emergence.

Mesocotyl length

The mesocotyl is an important part of the sorghum seedling, and its development during the emergence of the seed is a factor contributing to a good or bad establishment of the plant. Length and velocity of cell expansion are characteristics of specific genotypes. Planting depth and vigor in sorghum are associated with mesocotyl elongation. Maiti and Gutierrez (1989) compared 100 sorghum genotypes and concluded that mesocotyl elongation was associated with seedling vigor and the capacity of the genotypes to emerge from deeper planting depths. The mesocotyl length attained under deeper planting also showed a high heritability.

Radford and Henzell (1990) studied the effect of seven soil temperatures and eight grain sorghum genotypes on mesocotyl elongation. They found significant variations among genotypes, and the best temperature for mesocotyl elongation varied from 15 to 30°C.

Vigor Tests

Definitions

Seed vigor was first defined by Isely (1957) as “the sum total of all seed attributes which favor stand establishment under unfavorable field conditions.” Woodstock (1965) introduced an environmental component in his statement. Perry (1973) cited by McDonald (1993) worked with this topic and made modifications to the definition of vigor introducing genotypic and

environmental conditions. In 1977, the International Seed Testing Association (ISTA) formally defined seed vigor (McDonald,1993), and a more recent definition was developed by the Association of Official Seed Analysts in 1980 as "... those seed properties which determine the potential for rapid, uniform emergence, and development of normal seedlings under a wide range of field conditions " (AOSA,1986).

From the definitions and the application of the vigor tests, Norton (1986) pointed out that standard seed germination tests are not good indicators of field emergence. Because standard germination tests do not submit seed to stress, they show poor correlation with seedling emergence in the field, mainly due to adverse environmental factors.

McDonald (1993) observed that vigor tests are designed to reveal the field performance capability of the seeds; and, at that time, 75% of the seed testing laboratories routinely conducted one or more vigor tests. Ferguson (1993) emphasized that vigor tests are not designed to predict the exact number of seedlings that will emerge and survive in the field, although many of the vigor tests do correlate well with field emergence.

McDonald (1975), in a review and evaluation of vigor tests in seeds divided them into three categories: physical, physiological, and biochemical. As a definition of vigor tests, he suggested that they must reflect the seed's potential. Discussing the same subject, Matthews (1981) divided vigor tests into two groups according to their objectives. The first are rapid, inexpensive, and indirect methods (e.g. tetrazolium and electrical conductivity). The second are a group of vigor tests that are more directly indicative of field emergence (e.g. germination, seedling vigor, etc.).

Sorghum vigor and vigor tests

Germination and vigor problems in sorghum are usually related to weathering during the post-maturation, pre-harvest period or drought induced seed immaturity (Goggi et al., 1993). Weathering and immaturity also lower the specific gravity of seeds. Establishing four seed vigor levels and their influence in sorghum growth and development, Ogundipe (1984) found that low-vigor seeds produced plants with delayed times and rates of panicle exertion. Also yield decreased substantially as seed vigor level declined .

Souza and Marcos Filho (1975) evaluated sorghum seed vigor using standard germination, rate of germination, rapid aging, ammonium chloride stress test, and field emergence. They concluded that the results were highly correlated with seed quality; and, among the laboratory tests, the best predictors of seed vigor were germination velocity and ammonium chloride stress test. Yayock et al. (1975) concluded that a NH_4Cl stress test was best correlated with field emergence. In this test, the seed were soaked with a 4% solution for 1 to 2 hours at 40 or 50 °C, and the germination temperature was between 20 and 30°C.

Osmotic stress as a vigor test

The osmotic potential of a colloidal solution can mimic the soil water potential, and soil water potential is a most important parameter in controlling seed germination under normal farming conditions. Predicting field emergence using polyethylene glycol (PEG) as a water stress, Hadas (1977) found good correlation between field emergence and time needed to attain germination in a solution of PEG 6000 (MW) from -0.01 to -1.28 MPa water potential.

Comparison between two sorghum cultivars were made by Stout et al. (1980) using PEG 6,000 and 20,000 as osmotica. They concluded that this test can predict only the relative ability of a cultivar to germinate in soils of low water content.

Evans and Sticker (1961) used d-mannitol solutions as an osmoticum for sorghum seed stressing. They worked with four sorghum varieties under four moisture tensions and found that germination decreased as moisture tension increased. They also found differences among cultivars in germination rates.

Using six different PEG concentrations and 11 sorghum cultivars, Saint-Clair (1976) concluded that increasing concentrations of the osmoticum resulted in poorer germination. Marked differences among cultivars in germination were also shown in this experiment.

Sorghum seeds germinating in different osmotic potentials were observed by El-Sharkawi and Springuel (1977). They pointed out that radicle emergence was not affected by reduced osmotic potential except at potentials lower than -0.9 MPa. Gurmu and Naylor (1991) studied the effect of low water availability on germination of two sorghum cultivars. They found similarity of results when comparison were made between PEG and soil experiments. Lower water potential reduced water uptake, radicle and coleoptile emergence, and radicle length.

To overcome salinity stress of sorghum seed germination by hydration-dehydration treatment, Prisco et al. (1976) used NaCl and Na₂SO₄ as osmotic priming agents. Their results show that, when the seeds were not primed, the salts inhibited both germination and seedling vigor.

Santipracha (1986) used PEG at -1.27 and -1.72 MPa as priming agents on sorghum seeds at two temperatures to improve the germination performance. The osmotic conditioning improved the rate and the percent of germination at 15°C and -1.27 MPa.

Simulating drought resistance using PEG, Smith et al.(1989) applied osmotic potentials of -0.4, -0.8, and -1.2 MPa to sorghum seeds. They concluded that germination decreased steadily as osmotic potential increased. Garcia and Lasa (1991), studying several variables, showed that the variable which best predicted seedling emergence was the percentage of first seedling leaf emergence in a PEG solution at an osmotic potential of -0.6 MPa.

Using NH_4Cl and NaOH as osmotica to stress sorghum seeds, Vanderlip et al. (1973) found the highest correlation with field stand establishment when they used a NaOH treatment for 2 minutes. Studying the germination and emergence responses of grain sorghum to salinity, Igartua et al. (1994) used saline solutions of NaCl and CaCl_2 . Large genotypic differences were observed, for salt tolerance at germination and emergence stages. These differences were not related to the viability of seeds and were poorly related to seed weight, a factor considered as an estimate of intrinsic seed vigor.

Working with five water potentials ranging from 0 to -1.0 MPa using PEG 6000 solutions and two soils, Jayawardhana et al. (1989) concluded that PEG solutions inhibit germination of sorghum seeds. Germination was decreased significantly at the lowest potential of -1.0 MPa. Polyethylene glycol was a satisfactory osmoticum for studying the direct effect of water potential on germination. Sorghum seed germinability under moisture stress imposed by PEG 6000 at -0.2 to -1.0 MPa was studied by Dighe and Rajurkar (1981). Their results pointed out that germination energy declined with increases in osmotic concentrations, where germination energy is defined as the cumulative germination counts divided by the time interval.

Germination and seedling growth under PEG and NaCl were studied by Ashraf et al. (1990) with two sorghum cultivars. They concluded that both PEG and NaCl decreased germination, however, PEG was more effective than NaCl . The response to salinity indicated that one variety was tolerant, while the other was sensitive to NaCl . The effect of osmotic media on germination and seedling growth of one sorghum cultivar was investigated by Lad (1986) using mannitol and PEG 4000. The results indicated that germination percentage and radicle length decreased with increasing concentration of mannitol and PEG 4000.

Working with sorghum and other annual crops, Dart et al. (1992) used PEG 6000 and found that sorghum is more resistant to water potential and temperature increases than soybean and sunflower. The maximum germination of sorghum seed occurred in a range of 27 to 37°C at -1.2 MPa after 3 days.

Temperature stress as a vigor test

In many cases, temperature variations are responsible for differences in sorghum emergence and early seedling development. Germination is linearly affected by soil temperature, when soil water is not limited (Anda and Pinter, 1994). Studying soil temperatures and field emergence in Hungary, Anda and Pinter (1994) advised sorghum planting after the soil temperature is stabilized above 10°C.

Seeking to estimating field emergence of grain sorghum, Baskin et al. (1993) used dry and wet soil at cold and hot temperatures for laboratory emergence tests. Their results showed that cold and wet test correlation coefficients were the highest when related with field emergence, in comparison with hot and dry.

Van de Venter and Lock (1992) investigated heat shock and the response of seedlings to high-temperature stress (thermo-tolerance induction), and used the heat-shock protein synthesis response as an index of seed vigor in grain sorghum. They found a significant correlation of thermo-tolerance and field emergence under hot and dry as well as cool and wet soil conditions.

Oughan and Stoddart (1985) pointed out that failure of some grain sorghum lines to germinate and emerge at very high soil temperatures (45 to 50°C) is closely correlated with inhibition of embryo protein synthesis during the first few hours of imbibition. Oughan and Stoddart (1986) showed that cultivar differences were apparent in the time at which the capacity to synthesize heat-shock proteins first appeared. The susceptibility of early germination processes to high temperatures in some sorghum lines may be related to their inability to synthesize heat-shock proteins and acquire thermo-tolerance.

Conductivity tests

Seed electrical conductivity tests are usually assumed to reflect cellular membrane integrity and are determined by potential measurements of hydrated seeds or on seed steep water (Parrish and Leopold, 1978). These measurements show that the increases in steep water conductivity correlates well with other indicators of declines in seed vigor. Conductivity testing of seeds appears to be one of the more promising approaches for better assessment of the planting value and or storage potential of seedlots and for evaluation of seed treatments to maintain or enhance seed quality involving membrane integrity and seed coat characteristics (Pandey, 1992)

Garcia and Lasa (1991) used electrical conductivity tests to predict field emergence of grain sorghum. They found significant difference for seed leaching among genotypes, but the correlation with field emergence was not significant. McDonald (1975), in a review and evaluation of seed vigor tests, emphasized that measurement of the conductivity of leachate from seeds is a rapid, precise, and simple procedure. Weak seeds generally possess poor membrane structure, which results in greater electrolyte loss and higher conductivity measurements. Krishnasamy and Ramaswamy (1987) found that electrical conductivity of sorghum seed leachate correlated negatively with field emergence, standard germination, and vigor index. Conductivity did not correlate well with root length, shoot length, or dry weight of seeds.