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THE CONTRIBUTIONS OF PLANT NUMBER, SPATIAL DISTRIBUTION AND INDIVIDUAL PLANT VIGOUR TO GRAIN YIELD IN UNEVEN PLANT STANDS OF SUNFLOWER

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SUMMARY

Plant stands of sunflower were commonly quite variable in Central Queensland, but any impact on grain yield was not clear. Consequently, a method for quantifying yield loss was developed and used to survey crop establishment. The survey found losses in grain yield could be substantial. Work has proceeded to examine the sources of variation in the plant stand, and their impact on grain yield. In this paper, we review progress in understanding the contributions to grain yield of plant number, spatial distribution and individual plant vigour, in uneven plant stands of sunflower.

Crop establishment is important, because the yield potential of the crop is defined by the number, distribution and vigour of the individual plants in the stand. The target density should be obtained in each unit area of crop. Efforts should be directed to achieving a fast, even emergence with minimal gaps. Techniques for attaining these objectives are discussed in a separate review, relative to the importance of plant number, spatial distribution and individual plant vigour. Research to improve understanding of such characteristics is worthwhile, as this has assisted in identifying methods for achieving better plant stands, through the manipulation of agronomic practice, machinery design and pest management.

INTRODUCTION

Uneven plant stands are common in commercial crops of sunflower in Central Queensland (Spackman 1985). Whether this disuniformity resulted in significant loss in grain yield was not clear. No suitable technique was available for assessing the impact of heterogeneity in plant stand on grain yield (Wade *et al.* 1988). Consequently, our research focussed initially upon the yield consequences of uneven plant stands in sunflower. In this paper, we review progress in developing a suitable method for assessing yield loss due to a poor stand. The method is used to examine the contributions to grain yield of plant number, spatial distribution and individual plant vigour. The implications of this research are discussed.

A TECHNIQUE FOR EVALUATING PLANT STANDS

The plant stand interacts strongly with crop duration and water supply, by influencing mean plant size and the proportion of its final dry matter allocated to grain (Gardner and Gardner 1983). Plant density defines the number of plants per unit area which share the scarce resources required for growth. Plant arrangement, or the distribution of those plants within each unit area of crop, controls interception or retrieval of those resources. In commercial practice, plant stands are rarely uniform. Poor plant stand reduces yield, with potential yield lost from any section of crop in which plant number is inadequate (gaps) or in which plant number is excessive (clumps). Thus, there is both under-utilisation of, and excessive competition for, resources in the one stand (Wade *et al.* 1991).

In order to examine the consequences of suboptimal plant density and non-uniformity in plant spacing on grain yield, Wade *et al.*(1988) developed a multiple regression relationship between grain weight per plant, area per plant and individual plant coefficient of variation. Wade (1990) used the resulting equation to quantify the effects of plant density and plant stand uniformity on grain yield. This technique has now been independently validated (Wade *et al.* 1992a). The use of this methodology permits loss in grain yield due to poor crop establishment to be quantified, alternative strategies for soil insect control or planter design to be evaluated, and optimum spacing characteristics of a plant stand to be defined.

YIELD LOSS DUE TO A POOR PLANT STAND

The need to survey crop establishment was identified as high priority (Wood *et al.* 1987; Wood 1988), in order to quantify the level of establishment being attained by farmers, the extent of yield loss associated with suboptimal plant stands, and its economic consequences. The technique described above was used to survey summer crop establishment (Radford *et al.* 1989). Yield reduction ranged from 10 to 60% over all crops, averaging 31% for sorghum and 43% for sunflower in the Central Highlands of Queensland in 1987/88. Sections of crop in which plant number was inadequate provided the major contribution to loss in grain yield, due to under-utilisation of resources. This result is in agreement with recent work in sunflower, which showed that gaps greater than 2 m (in 1 m rows) reduced yields substantially (Wade *et al.* 1992). Clumps were a minor contributor to loss in grain yield in the survey, because the plant densities attained were generally lower than those considered desirable. For raingrown sunflower crops, the recommended plant density is 40 000 to 60 000 plants/ha; for irrigated crops 100 000 plants/ha (Radford 1978; Wade and Foreman 1988).

AN IMPROVED TECHNIQUE FOR EVALUATING PLANT STANDS

The survey technique utilised by Radford *et al.* (1989) is time and labour intensive, because of the need to obtain grain weights of individual plants. Further analysis of the survey data has revealed positive linear relationships between the percentage loss in grain yield and indices of spacing uniformity (Wade 1990). If these relationships are reproducible, they may greatly simplify the requirements for future assessments of loss in grain yield due to a poor plant stand. This analysis is currently in progress (Wade *et al.* (1992a). The development of a simple technique would permit farmers to assess the suitability of their own plant stands. This represents an initial step in examining what constitutes an inadequate plant stand, what yield compensation is likely, and whether or not to replant. A replant decision would depend on the dynamic balance between compensation from neighbouring plants and rows on the one hand, and the likelihood of a suitable planting opportunity and its yield expectation on the other (Johnson and Mulvaney 1980). A project addressing yield compensation and replant decisions in sunflower has recently commenced (Winter *et al.* 1992).

PLANT SPACING AND TIME TO EMERGENCE IN AN UNEVEN PLANT STAND

For the original data set, the regression technique of Wade *et al.* (1988) accounted for 50% of the variation in grain yield contribution by individual sunflower plants in the stand. The remaining variation was attributed to factors not considered in the regression, including seed size, depth of seed placement, time of emergence, the quality of the microenvironment for seedling establishment and subsequent growth, and the proximity of neighbouring plants in adjacent rows. These factors alter the competitive ability of the seedling relative to its nearest neighbours, (seedling vigour), altering the proportional share of the limiting resource which each plant may intercept or retrieve. In the establishment survey (Radford *et al.* 1989), the regressions accounted for only 24% of the variation in grain yield contribution by individual plants. The greater contribution of seedling vigour on farm, relative to controlled field experiments, reflects the compromise in machinery setup and speed of operation necessary, when large areas need to be sown at each planting opportunity. Wade *et al.* (1992a) report significant improvement in accountability, when a term for seedling vigour, based on time to emergence of individual seedlings, is added to the regression. Time of emergence and its interaction with area per plant accounted for a significant proportion of the remaining variation.

SEED AND SEEDLING VIGOUR

Attaining an effective plant stand is influenced by seed viability and vigour (TeKrony and Egli 1991). Seed vigour comprises those properties which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions (AOSA 1983). Such seed potential is subject to the influences of the seedbed, before any consequences for seedling vigour are expressed. In a recent review, TeKrony and Egli (1991) concluded that seed vigour may influence vegetative growth, but normally bears little relationship to grain yield in field crops which are harvested at full reproductive maturity. Seed vigour influenced yield, but only when low plant density limited dry matter accumulation.

Seedling vigour may influence contribution to grain yield of seedlings differentially disabled by stress during establishment. Disability of remaining seedlings, following the mortality of their cohorts, has been shown to follow the incidence of high soil surface temperature and high soil water deficit (Abrecht and Bristow 1990). Using crop simulation, Carberry and Abrecht (1991) demonstrated the consequences of this disability for reduced grain yield. Variation in seedling vigour of individual plants, as measured by their time of emergence, could negate any yield advantage of greater precision in plant spacing in rice (Counce 1992). The presence of late-emerging corn plants reduced grain yield, even in high yielding environments (Nafziger *et al.* 1991). Similarly, late emerging sunflower plants contributed less yield than their early emerging cohorts, even when they had adequate space (Wade *et al.* 1992a). These results demonstrate the importance of fast even emergence, and the desirability of minimising any significant gaps in the stand.

We believe that seed and seedling vigour are critically important to successful crop production in semi-arid environments, via indirect effects on grain yield caused by reduced plant number, poor distribution or disability of the individuals in the stand. Any disability to the seedling resulting from delayed emergence has the potential to deleteriously affect crop performance. Whether grain yield will be reduced will be dependent upon subsequent seasonal conditions.

CONCLUSIONS

Crop establishment is important, because the yield potential of the crop is defined by the number, distribution and vigour of the individual plants in the stand. The target density should be attained in each unit area of crop. Efforts should be directed to achieving a fast, even emergence with minimal gaps. Techniques for achieving these objectives are discussed in a separate review (Wade *et al.* 1992b), relative to the importance of plant number, spatial distribution and individual plant vigour. Research to improve understanding of such characteristics is worthwhile, as this has assisted in identifying methods for achieving better plant stands, through the manipulation of agronomic practice, machinery design and pest management.

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