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Full Length Research Paper

Comparative response of direct seeded and transplanted maize (*Zea mays* L.) to nitrogen fertilization at Zanyokwe irrigation scheme, Eastern Cape, South Africa

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Previous studies carried out in smallholder irrigation schemes in South Africa showed that bird damage to emerging seedlings reduced crop stand and yield of maize. Transplanting offered an opportunity to improve stand but there was no information on fertiliser management of transplants. An on-farm experiment was therefore conducted to compare the response to nitrogen (N) rate (60, 120, 180, 240 and 300 kg N ha-1) of direct seeded and transplanted maize. Transplanting resulted in a significantly higher crop stand of 96% compared to direct seeding, which achieved 78%. Transplanted maize had shortened growth duration in the field, reaching flowering stage 11 to 15 days earlier than direct seeded maize. At low N rates, transplants produced higher green cob weight, grain yield and longer cobs than direct seeded maize. The economically optimum N rates required to obtain marketable cobs were 149 and 98 kg ha-1, whilst those required for achieving optimum grain yields were estimated at 240 and 227 kg ha-1 with direct seeding and transplanting, respectively. The findings suggest that transplanted maize can be grown at lower N rates to achieve similar yield potentials as direct seeded maize, and that transplanting can help in improving crop stands in areas where bird damage on emerging seedlings is a problem.

Key words: Crop stand, direct seeding, maize yield, N rate, transplanting.

INTRODUCTION

Smallholder irrigation cropping systems in South Africa (SA) have been described as comprising of mainly maize (Zea mays L.) in summer and vegetables in winter (Machethe et al., 2004; van Averbeke, 2008). Maize is grown for utilisation as either green cobs for table maize, grain or both. However, grain yields obtained by smallholder farmers have been observed to be far below the potential of 7 to 12 t ha-1 possible under irrigation (USDA, 2003). Bembridge (2000) cited yields of less than 2 t ha-1 as common, whilst van Averbeke et al. (1998) reported average grain yields of 3.7 t ha-1 in six smallholder irrigation schemes in the Eastern Cape province and Machethe et al. (2004) grain yields ranging between 1.6 and 4.2 t ha-1 in Limpopo. Grain yields achieved by farmers in Zanyokwe irrigation scheme (ZIS) in the Eastern Cape during the 2006/07 season averaged 1.8 t ha-1 (Fanadzo, 2007). These low yields have been largely attributed to poor agronomic practices, with low fertiliser and plant population levels being among the most important factors limiting maize productivity (Monde et al., 2005; Fanadzo, 2007).

For irrigation to be profitable, yields must be high, implying greater nutrient uptake by crops, since nutrient uptake is roughly proportional to crop yield (Crosby et al., 2000). The recommended fertiliser rates for irrigated maize vary depending on yield potential, but can be as high as 220 kg N ha-1 for a yield target of 10 t ha-1 in SA (FSSA, 2007). However, a monitoring survey conducted at ZIS showed that on average, farmers applied only 47.6 kg N ha-1 (Fanadzo et al., 2009). This rate of N is consistent with the low average maize yields observed in

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ZIS. When other nutrients are not limiting, it is generally observed that added N can double or triple the yield when adequate water is available to a growing crop (Thomson et al., 2000).

Agronomic research on maize has largely focused on maximising grain production, but research aimed specifically at optimising green maize production is lacking (Van Averbeke, 2008). Damage of emerging maize seedlings by birds is a serious problem in ZIS and other smallholder irrigation schemes in the Eastern Cape that results in poor crop stands and low yields (van Averbeke et al., 1998). Transplanting is a strategy that is commonly used to establish crops when conditions are less favourable for direct seeding such as when birds pose a threat to emerging seedlings. The practice is commonly used in rice cultivation and in the production of vegetable crops. According to FAO (2003), maize transplanting is most common in Korea but it has been reported in other parts of the world such as North Vietnam (CIMMYT, 1989) and Northern India (Sharma et al., 1989; Khehra et al., 1990).

The use of transplants shortens the growth period in the field such that even late-maturing, high yielding cultivars can be made to fit into available growing season as dictated by either rainfall or temperature (Dale and Drennan, 1997). Depending on the age of transplants, time to harvest of maize was reduced by one to three weeks in the USA and 10 to 12 days in France (Waters et al., 1990). In SA, maize transplanting is used by some commercial farmers for production of green maize. However, few if any, smallholder farmers in SA practice it. Whilst the response to N rate of direct seeded maize has generally been studied (FSSA, 2007), information is lacking on the response of transplanted maize. This study was therefore carried out to determine maize yield response to N rate with direct seeding and transplanting. The hypotheses tested were:

(i) Maize responds better to N when transplanted than when directly seeded.
(ii) Use of transplants result in superior crop stand compared to direct seeding.

MATERIALS AND METHODS

Experimental sites

The studies were conducted at ZIS (32° 45´S, 27° 03´E) in the central Eastern Cape province of South Africa. Mean annual rainfall in the area is 580 mm of which about 445 mm is received in summer, thus necessitating supplementary irrigation (van Averbeke et al., 1998). The experiments were planted at one farm; Bantubantu during the 2006/07 season and at two farms; Kalawe and Booi in 2007/08. Bantubantu and Booi farms (32° 45´S, 27° 03´) have dark coloured heavy textured soils of the Valsriver form (Soil Classification Working Group, 1991). Kalawe farm (32° 46´S; 26° 50´E) has deep alluvial soils of the Oakleaf form, belonging to Jozini series (Soil Classification Working Group, 1991). Bantubantu was planted on 18th December 2006 while Kalawe farm and Booi were planted on 20th and 22nd November 2007, respectively.

Experimental design and treatments

The experiment consisted of two factors; N rate and establishment method laid out as a 2 × 6 factorial in a randomised complete block design with three replicates per site. Establishment method was at two levels, direct seeding and transplanting whilst N rate was at six levels; 0, 60, 120, 180, 240 and 300 kg ha-1. A third of the N was applied as a basal application at planting as compound fertilizer 2:3:4 (30) while the remaining two thirds were applied as lime ammonium nitrate (28% N) top-dressing in two equal splits at 5 and 7 weeks after emergence (WAE). Gross plots consisted of 11 rows each 6 m long, and spaced 0.9 m between rows. The corresponding net plots consisted of four middle rows each 4 m long for the green and grain yield assessments. Two-week old containerised seedlings were purchased from a commercial nursery about 20 km from the study area. Planting of seedlings was done using a hollow cone dibber which made a hole matching the size of the seedling's root ball on its removal from the tray. Seeds were sown at the same time as transplanting in holes opened by hand hoes. The newly established crop received an irrigation of 18 mm soon after sowing/transplanting.

Agronomic practices

Land was ploughed and disked once using a tractor-drawn plough and disc harrow, respectively, before the plots were marked. Maize variety SC 701 (Seed-CO®, South Africa) was used. Three seeds were planted at in-row spacing of 0.27 m in rows 0.9 m apart for a target population of 41 152 plants ha-1. Thinning was done 2 WAE to leave one plant per hole. The crop was kept weed free through a combination of chemical and mechanical weed control methods. Atrazine was applied soon after planting/transplanting at a rate of 4 litres ha-1, while weed escapes were removed through hand pulling and hand hoeing. Supplementary irrigation was applied as shown in Table 1. Maize stalk borer (Buseola fusca Fuller) was controlled by applying Bulldock® (active ingredient: pyrethroid) granules in the maize funnel at 2 weeks after transplanting seedlings and 4 WAE in the case of direct seeded maize.

Measurements

Crop stand was measured in net plots at 21 days after sowing/transplanting. Dates at which 50% of the plants reached the flowering and milk stages were noted in the net plot area. The stage of kernel development was monitored by cutting a flap in the husk, which could be lifted over the central part of the cob to reveal the developing kernels. The flap was closed and stuck down with a masking tape after completing the inspection. Green maize yield was evaluated by total weight and average cob length. Cob length was measured when the maize was ready for marketing on twenty randomly selected plants in the net plots. Marketable cobs were considered to have a length equal to or above 33 cm, and showing a healthy grain set suitable for commercialisation. Maize for green cobs was harvested at the milk stage. Grain maize was harvested at physiological maturity (defined as black layer formation at the base of the kernels). Grain yield data was taken from Kalawe and Booi farms.

Statistical procedures

Crop stand, time to 50% flowering and milk stages, green cob weight and length, and grain yield were subjected to analysis of variance. Statistical analysis was performed using Genstat Release 7.22 DE on a per site basis and Bartlett's test (Gomez and Gomez, 1984) carried out to compare mean quare error variances before

Table 1. Rainfall and irrigation water (mm) received during maize crop growth.

Month	2006/07			2007/08			Mean temperatures (°C)	
	Rainfall	Irrigation	Total	Rainfall	Irrigation	Total	2006/07	2007/08
November	45.3	48	93.3	38	48	86	19.1	19.0
December	43.4	59	102.4	124.7	36	160.7	20.0	21.6
January	48.3	64	112.3	104.7	36	140.7	22.8	22.1
February	74.2	122	196.2	96.5	18	114.5	23.2	22.6
March	90.7	-	90.7	65.2	-	65.2	20.0	20.8
April	26.3	-	26.3	48	-	48	19.0	16.9
Total	328.2	293	621.2	477.1	138	615.1	-	-

Table 2. Number of days to 50% flowering with direct seeding and transplanting at varying N rates.

Establishment method	N rate (kg ha-1)					
	0	60	120	180	240	300
Seeded	79	74	71	69	69	69
Transplanted	64	61	59	58	58	58
LSD (0.05)	0.5					

Table 3. Number of days to milk stage with direct seeding and transplanting at varying N rates.

Establishment method	N rate (kg ha-1)					
	0	60	120	180	240	300
Seeded	117	109	103	101	100	100
Transplanted	94	86	83	82	82	82
LSD(0.05)	0.69					

combining across sites. Grain yield was standardised to 12.5% moisture content before statistical analysis. Unless otherwise stated, differences referred to in the text are significant at $p < 0.05$.

RESULTS

Crop establishment and development

Plant stand: Establishment method × N rate interaction and main effect of N rate were not significant. Establishment method was significant ($p < 0.01$). Transplanting achieved a stand of 39 672 plants ha-1 (96% of target) compared to 32 272 plants ha-1 (78% of target) with direct seeding.

Days to 50% flowering and milk stages: There was a significant ($p < 0.01$) establishment method x N rate interaction with respect to days to 50% flowering (Table 2) and days to milk stage (Table 3). Transplanting resulted in a smaller difference in days to 50% flowering between zero and optimum N rate of 180 kg ha-1 compared to direct seeding. Similarly, there was a difference in days to milk stage between zero and optimum N rate with transplanting compared to direct seeding.

Green Cob weight: Establishment method × N rate interaction was significant ($p < 0.01$) (Figure 1). The main effects of establishment method, N rate and site were all significant ($p < 0.01$). At low N rates, transplants yielded higher than direct seeded maize, but fertilisation at 300 kg N ha-1 resulted in similar green cob weight.

Cob length: Establishment method x N rate interaction was significant ($p < 0.01$) (Figure 2). The main effects of establishment method and N rate were also significant ($p < 0.01$). Transplanted maize produced longer cobs than direct seeded maize at N rates up to 120 kg ha-1, but there was no difference beyond this N rate required for the production of a marketable cob was 149 kg N ha-1 with direct seeding and 98 kg N ha-1 with transplanting (Figure 2). The maximum cob length obtainable at the maximum N rate of 300 kg ha-1 was estimated to be 40.6 cm, regardless of establishment method (Figure 2).

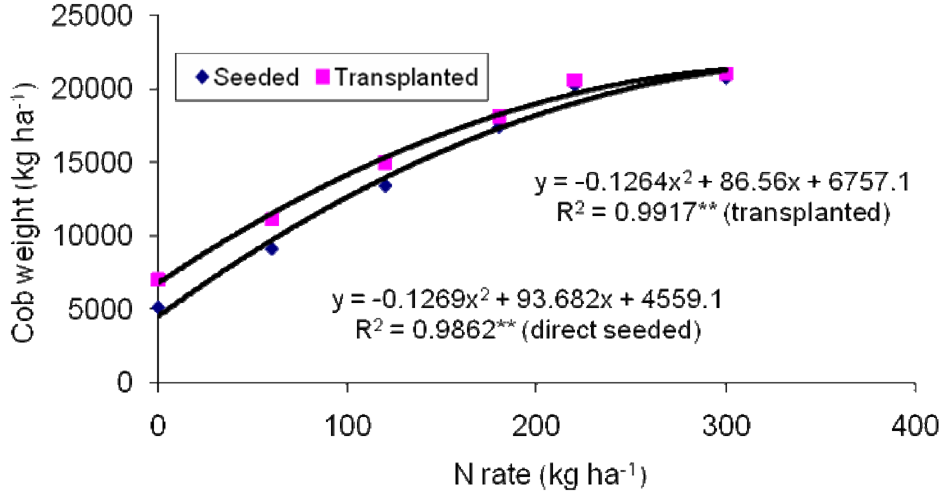

Figure 1. Green cob weight at varying N rates with transplanting and direct seeding.

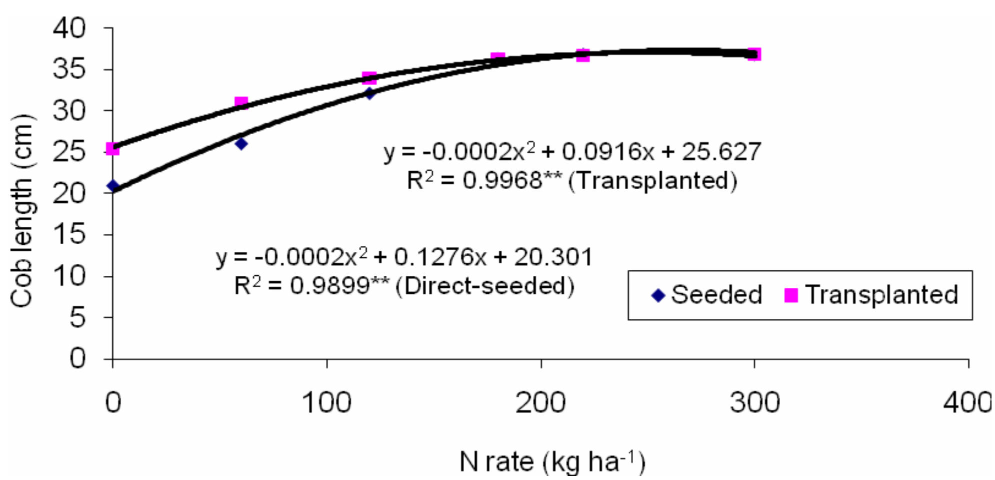

Figure 2. Relationship between establishment method and N rate on maize cob length.

Grain yield at Kalawe and Booi farms

Establishment method × N rate interaction and N main effect were significant ($p < 0.01$). Transplanting yielded higher than direct seeding at N rates up to 180 kg ha-1 and there was no difference beyond this N rate. To estimate the economically optimum N rate, the equations that described the yield responses (Figure 3) were used. The first derivative of the response function was equated to the ratio of fertiliser cost (That is. R43.10 kg-1 N) to grain price (That is. R2.00 kg-1) (Havlin et al., 1999). From the equations, the economically optimum N rate was estimated at 227 kg N ha-1 for transplanted maize and 240 kg N ha-1 for direct seeded maize. These N rates correspond to grain yields of 10.0 t ha-1 for direct seeded maize and 9.9 t ha-1 for transplanted maize, which were not significantly different.

DISCUSSION

Results of this study indicated a significant improvement in crop stand with transplanting. The reduction in crop stand with direct seeding was as a result of crows (Corvus corax) which fed on the emerging seedlings. In green maize production, a higher crop stand with acceptable cob size would mean higher income per given unit of land since price is charged per cob. Plant density is one of the most important cultural practices agronomic attributes of maize (Sangoi, 2000). Thus, transplanting is a strategy that can be used to achieve optimum plant densities and optimize on yield in areas such as ZIS where bird damage is a serious problem.

The study showed that use of transplants and/or fertilisation at higher N rates resulted in earlier maturity and higher yields than direct seeding and/or use of low

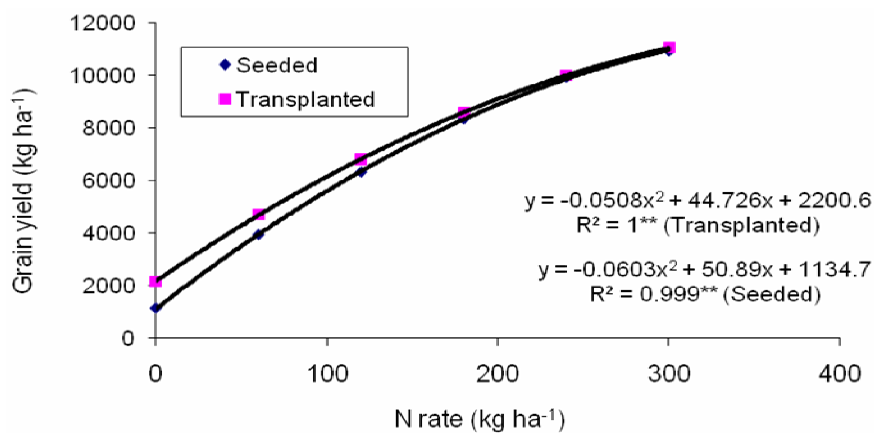

Figure 3. Relationship between establishment method and N rate on maize grain yield.

N rates. More rapid growth at higher N rates and/or with transplanting would contribute to improved water use efficiency resulting from both shorter crop duration and higher yields. In this respect, the disadvantage of direct seeding and/or fertilisation at low N rates would be two-fold; longer crop duration (hence low cropping intensities or poor timing of planting operations for subsequent crops and more water consumption) and losses to the farmers as a result of failure to produce marketable green cobs or low grain yields. The results showed that transplanted maize required lower N rates to achieve similar yield levels to those realized with direct seeded maize. Nitrogen rate could be reduced by as much as one third with no loss in marketable cobs. Its adoption by smallholder farmers could help them realize higher yields compared to direct seeding since they generally apply low fertilizer N rates to their crops.

Transplanted maize required less N compared to direct seeded maize because some nutrients had been applied to seedlings when they were being raised. In addition, since containerised as opposed to barerooted seedlings were used, these had additional nutrients contained in the root balls. The fact that the economically optimum N rate required to obtain marketable green cobs was lower than that required to obtain optimum grain yields regardless of establishment method suggests that for purposes of green maize production, lower N rates can be used as compared to grain maize production. Maize grown for green cobs takes shorter growth duration in the field compared to grain maize, and hence lower amounts of nutrients would be required for growth and development.

Soil moisture and nutrients are complementary inputs such that the incremental productivity of water is a function of the amounts of nutrients available, just as the incremental productivity of nutrients is a function of soil moisture (Wichelns, 2006). Earlier maturity and higher green cob weight and grain yield parameters with higher N rates may be attributed to increase in photosynthetic rate, leaf surface area and size of the sink as described by Aluko and Fischer (1987). Sinclair and Horie (1989) attributed increase in leaf area and photosynthetic capacity to the effects of N on cell and tissue growth. With respect to establishment method, results of this study concur with those of Dale and Drennan (1997) who reported earlier maturity and higher yields from transplants compared to direct seeded maize.

The labour-intensive process of manual transplanting used for this study is of little interest for commercial maize production. However, the present and future trends in South African agriculture emphasize the need for land management with minimal soil disturbance to reduce soil erosion and nitrate leaching through conservation agriculture, and minimal use of herbicides through integrated weed management. These conditions may be well suited to transplanted maize as results of a study done in Germany suggested (Scheffer, 1984, 1987). To provide a permanent soil cover which would reduce soil erosion and nitrate leaching, the maize would be transplanted by machinery into the unploughed stubble of a preceding crop (Dale and Drennan, 1997). Scheffer (1992) has also shown that use of transplants can help to lower herbicide requirements since the rapid growth of the maize seedling transplants tends to be more competitive with weeds than the slow establishment phase of direct seeded maize.

In this study, both transplanting and direct seeding was done at the same time soon after winter because the objective was to compare maize performance with direct establishment methods and N rates. Planting could not be done earlier as the temperatures would be too low to establish a direct seeded crop. Future studies need to investigate the possibility of transplanting early, towards the end of spring but when conditions are still not conducive for direct seeding, to catch the early market in December when demand for green maize is high.

Conclusion

This study demonstrated opportunities that exist in optimising green and grain maize yields through transplanting. It has been demonstrated that transplanting can help in achieving a good crop stand which would translate to more green cobs and higher grain yields. Applying low N rates to maize slows crop growth, resulting in maize taking a longer duration to reach maturity. However, transplanted maize can be grown at lower N rates to achieve similar yield levels as direct seeded maize, and in a shorter duration. Lower rates of fertiliser N can be used when maize is grown for utilisation as green cobs than when it is grown for grain. The economically optimum N rates required to obtain marketable cobs were 149 and 98 kg ha-1, whilst those required to achieve optimum grain yields were 240 and 227 kg ha-1 with direct seeding and transplanting, respectively.

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