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Responses of Maize (*Zea mays*) Seed Germination Capacity and Vigour to Seed Selection Based on Size of Cob and Selective Threshing

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Abstract: Farm-saved seed accounts for the greatest proportion of seeds used by farmers worldwide especially in low-income countries. One way through which farmers have been able to improve quality of the farm-saved seed is seed selection. In maize, grains can be selected in terms of, in addition to health, kennel size. One way of easing selection based on kernel size may be selection of ears and discriminative threshing of the ears. A study was conducted at Sokoine University of Agriculture in Tanzania to determine effects of selecting different sizes of ears and threshing discriminatively grains positioned in basal, distal and middle areas of the ears. Grains so selected were tested for germination capacity and vigour. Results showed that as expected larger ears and basal position of grains were accompanied with larger size of kernels. Size of ears did not influence grain germination capacity but it had significant effects on grain and seedling vigour. Grains from very small ears were earliest to germinate (lower mean germination time, MGT), which is an expression of high grain vigour. However, grains from larger ears and basal positions in ears (consequently larger kernel size) led to significantly ($P \leq 0.05$) more vigorous seedlings (larger seedling dry weight). Basal position of kernels resulted in significantly higher germination capacity and larger seedling dry weight than distal position. It can be concluded that selection of ears and selective threshing of the ears with avoiding distal position kernels can also be important criteria in quality improvement of maize grains.

Key words: Ear selection · Discriminative threshing · Kernel position · Basal position · Distal position · Grain vigour · Seedling vigour · Mean germination time

INTRODUCTION

Maize is a cereal crop of great importance in the tropics and sub-tropics particularly in Africa and South America where, according to Sprague [1], it is the most important food crop. There are many varieties of the crop ranging from composites to hybrids, improved and landrace populations. It is a crop where probably most notable success in plant breeding has been achieved in terms of varieties developed and seeds made available to farmers. It is also a crop where farmers for a long time have been able to handle it's seed and use it for raising the next crop from their own seed sources. Statistics show that, for example, about 80% of maize production in Tanzania is produced by small farmers and that improved varieties and husbandry practices account for a very small proportion of the crop produced [2]. Currently, even though the crop is very widely cultivated in the country, it is only a very small percentage (less than 10%) of the national improved seed requirement that farmers use by purchasing from commercial channels [3,4]. The rest of the requirement is farm-saved seed produced by farmers themselves from previous season grain crop. In most of the developing countries the informal seed sector is indeed reported to dominate seed supply, as much as 90-95 % and even above, in general and depending on crop [3,5-7].

Farmers have a long experience of using their own seed saved from the previous crop harvest. Indeed, organized commercial seed supply of improved crop varieties worldwide is a very recent practice that has been in existence for less than a century (most of modern improved crop varieties and their organized seed supply systems are associated with hybrid maize produced in the Corn belt in USA beginning in late 1930s [8]). This means that for centuries and millennia farmers have been using and handling seed traditionally and this was able to sustain production and food availability. Occasionally these farmers were able to improve quality of the seed they use in various ways.

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One of the traditional but very important method that farmers use to improve quality of their seed is seed selection. This practice has been able to increase yield and crop performance in many ways. More stabilized plant population in the field has been one of the most significant advantages of seed selection. Seedling emergence up to about 60% better [9] has been reported in rice based on selection against shriveled, spotted, discoloured seeds or seeds floating in brine solution; and an average of about 12-13.3% in maize [8,10] based on selection of 'clean' against 'un-clean' (no selection) seeds. Yield increases as a result of seed selection (manual sorting or cleaning) have also been reported, of up to 50% in wheat [11]; 24% in rice [12]; 15.3% in okra [17] *et cetera* [14-16].

In maize seed selection is a very common traditional practice. Careful farmers have always selected largest and most healthy-looking and best filled cobs and handled them separately for seed. During planting or threshing sometimes the farmers avoid seeds from the immediate basal end or distal end of the cob, which are usually small in size. Sometimes if farmers just take the seed from reserves of the threshed grain crop they may sort the seed and select for size, against insect damage, microbial decay and discolourations, cracks or any sort of mechanical damage. Seed selection in maize has been found to increase yield for about 43.2% [10].

MATERIALS AND METHODS

Research reported in this paper started with selection of maize ears harvested from approximately one hectare field that was planted with maize variety Staha. The ears were selected on basis of size variation and were categorized as very large, large, medium, small and very small after measuring their lengths and diameter. Very small ears were generally those less than 10cm in length and diameter less than 5cm (or not exceeding 4cm if length was up 15cm). Very large ears were generally those more than 20cm long and diameter more than 6cm. The rest of the ears were intermediate (small, medium, large) categories. This categorization was based on observation of the harvested ears for the variety (Staha) that longest ears were between 20 up to 30cm; most of the shortest ears were more than 10cm in length; and thickest ears were more than 6cm diameter and most of the thinnest ears were between 3-4cm in diameter. After selection of the ears they were individually threshed separating grains from the distal end (small rounds), basal end (large rounds) and the middle (middle flats). Threshed grain samples were then collected and labeled appropriately, their 100-grain weight measured and then subjected to germination and vigour assessment. Germination test was performed using sand in Aluminium bowls/pots. Data was collected on percent germination capacity, vigour in terms of seed's speed of germination (mean germination time, MGT) and vigorousness of seedlings (10 days old) in terms of dry weight of the seedlings; and length measurements of the shoot and roots of the seedlings.

RESULTS AND DISCUSSION

It is evident from the study that size selection of ears and selective threshing (or in other words size selection of grains) can improve quality of maize grains quite appreciably. Fig. 1 shows generalized effects of ear

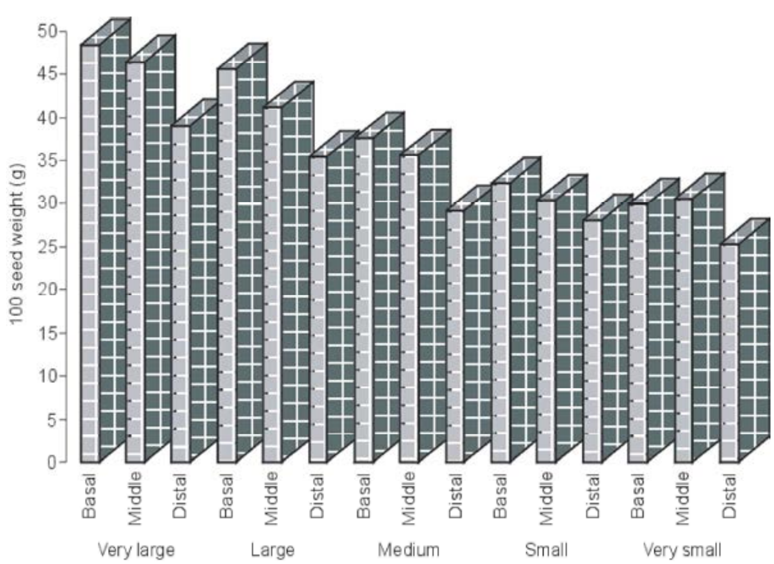

Fig. 1: Relationship between ear size and basal, middle and distal kernel positions on kernel size in maize (Zea mays)

Table 1: Effects of size of ears on seed germination and seedling characteristics in maize

Size of ears	Germination capacity (%)	Mean germination time (days)	Shoot height of seedling (cm)	Seedling root length (cm)	Seedling dry weight (g/pot)
Very large	97.3	3.39	15.7	24.9	19.45
Large	96.9	3.27	16.6	25.0	20.27
Medium	98.9	3.21	16.0	23.7	20.48
Small	96.8	3.33	15.8	23.4	15.21
Very small	98.2	3.18	16.2	22.7	14.47
Mean	97.6	3.28	16.1	23.9	18.0
S.E. ±	0.92	0.04	0.30	0.76	0.16
CV (%)	2.0	2.6	4.0	6.8	1.9
$LSD_{0.05}$	ns	0.08	ns	1.55	0.33

Table 2: Effects of kernel position in maize ears on grain germination and seedling performance

Kernel position	Germination capacity (%)	Mean germination time (days)	Shoot height of seedling (cm)	Seedling root length (cm)	Seedling Dry weight (g/pot)
Basal	98.4	3.25	16.26	23.7	19.84
Middle	98.67	3.30	16.26	24.8	18.67
Distal	96.4	3.27	16.02	22.98	17.03
Mean	97.8	3.27	16.18	23.85	18.51
S.E. ±	0.72	0.03	0.23	0.59	0.12
CV (%)	2.0	2.6	3.9	6.8	1.8
$LSD_{0.05}$	1.47	Ns	Ns	1.2	0.25

Table 3: Combined effects of size of ear and kernel position on grain germination and seedling characteristics in maize

Ears size	Kernel position	Germination capacity (%)	Mean germination time (days)	Shoot height of seedlings (cm)	Seedling Root length (cm)	Seedling dry weight (g/pot)
Very large	Basal	99.3	3.32 ab	16	24.03 abc	20.86 e
	Middle	98.7	3.35 ab	15.5	24.43 abc	19.03 d
	Distal	94	3.5 bc	15.73	26.37 bc	18.45 d
Large	Basal	96.7	3.33 ab	17.1	25.23 abc	21.21 ef
	Middle	98	3.18 a	16.4	27.53 c	20.41 e
	Distal	96	3.29 ab	16.3	22.2 ab	19.2 d
Medium	Basal	99.3	3.21 a	15.93	21.97 ab	21.82 f
	Middle	99.3	3.17 a	16.26	25.97 bc	21.01 ef
	Distal	98	3.24 a	15.73	23.43 abc	18.96 d
Small	Basal	99.3	3.17 a	16.67	24.37 abc	19.22 d
	Middle	95.3	3.61 c	15.03	23.43 abc	14.3 b
	Distal	95.3	3.2 a	15.87	22.43 ab	15.46 c
Very small	Basal	97.3	3.21 a	15.6	23.9 abc	16.09 c
	Middle	98.7	3.21 a	16.63	23.03 abc	14.23 b
	Distal	98.7	3.15 a	16.53	21.23 a	13.08 a
Mean		97.6	3.28	16.08	23.94	18.22
S.E. ±		1.6	0.068	0.52	1.33	0.279
CV %		2	2.6	4.0	6.8	1.9
Probability		ns	0.001	ns	0.01	0.001

Means bearing the same letter in a column are not significantly different. Mean separation by DNMRT ($P \leq 0.05$) ns = Not significant

size and position of kernels in ears on size of the kernels in terms of dry matter accumulated (100-grain weight). Larger ears and basal position of kernels were consistently associated with larger grains while smaller ears and distal position of kernels led to smaller grains. Size of grains reflects quantity of food reserves and physiological biosysnthates that can be available to support growth during germination and early seedling establishment.

The effects of size of ears and kernel position on grain germination and grain and seedling vigour are shown in Tables 1, 2 and 3. Table 1 shows that even though size of ears did not influence grain germination capacity ($P \leq 0.05$), it had significant effects on grain and seedling vigour. Grains from very small ears were earliest to reach median germination (shortest mean germination time) which is indication of high grain vigour. Contrarily grains from very large ears were slowest in germination

($P \leq 0.05$). As already indicated grains from smallest ears were also smallest in size. The results on germination time suggest that the threshold level for growth activation in grains may be reached much earlier when quantity of food reserves and metabolites in the grains is smaller, as it should be expected in small size grains.

Results of this study probably show the influence of stored food reserves in grains on early seedling growth. The results show that even though smallest size grains germinated much more quickly it is seedlings from medium and large ears (larger size grains) that accumulated larger quantities of dry matter during the period of germination test (10 days). Seedling dry weight of grains from the smallest ears (smallest grains) was also smallest and significantly smaller than weight of seedlings from all other ear sizes. Thus it is probable that the mechanisms that control grain vigour in terms of how quickly the grains germinate are different from the mechanisms that control vigour in terms of seedling establishment. It may be true that even though smallest grains germinated most rapidly, larger grains establish the root system and the shoot system much more quickly after germination so that they are more able to absorb nutrients within their reach and photosysnthesize food that is assimilated for growth.

As already mentioned selection of ears as well as selective threshing of grains based on kernel position on ears or in other words size grading of grains can also be criteria for quality improvement in maize grains. Table 2 shows that grains threshed from the basal position of ears (the large rounds) produced significantly more vigorous seedlings according to seedling dry weight and had higher germination capacity ($P \leq 0.05$) than grains from either the middle position of ears (middle flats) or from the distal position (small rounds). It is therefore evident from these data that grains from the basal position are better in quality than especially grains from the distal position. Where ears can be selected and grains can be selectively threshed from different ear positions it seems advisable to avoid grains from the distal position because of their low vigour. Less vigour has been associated with lower subsequent yields in various crops [17-19], so the distal position grains if planted will contribute to yield reduction. Distal position is also more vulnerable to infestation by fungi and insect pests because of much exposure than lower position of the ear; this definitely will also contribute to inferior quality.

Further analysis of the influence of ear size and kernel position considers the interactive effects of the two (treatment) attributes. Of the parameters measured germination capacity and seedling shoot height did not show any significant interaction of ears size and kernel position. Significant interaction existed for the rest of vigour parameters (viz. MGT, seedling dry matter and root length). In terms of MGT, it seems size of ears was not very determinant of the observed interactions. Whether large or small cobs MGT for different ear positions was almost the same statistically ($P \leq 0.05$) except for one deviation (small ears, middle position), which, additionally, did not indicate any definite trend (Table 3). The results have shown, however, that MGT for different ear sizes was statistically the same only when grains were from the basal position regardless of size of ears; when they were from middle and distal positions, that is when MGT showed variation with size of ears.

In terms of seedling dry matter the results showed that for each ear size seedling dry matter content decreased from basal to distal kernel positions (one exception) and that for each ear size seedlings from basal position grains accumulated significantly much more dry matter ($P \leq 0.05$) than at least one of the other positions. The results further showed that most vigorous seedlings were those from grains originating from basal and middle positions for large, very large and medium ears. Variability among these was very little. Seedlings from distal positions and from very small ears were very significantly lower in vigour.

The results further showed that even though significant interactions existed on root length, another vigour parameter, the parameter did not show very distinctive variations with size of ears and kernel position. It seems, however, that there was tendency of large ears producing seedlings with longest roots no matter what was the position of the kernels. The results also showed that wherever there was significant interaction distal position grains from smallest cobs had least quantitative value of the parameters measured. In terms of MGT this means they were quickest to germinate.

There is an indication that whatever was observed in one parameter was in most instances related with what was observed in another or other parameters measured. Information like this can be assured from correlation analysis. Table 4 shows correlation matrix of the various grain and seedling parameters measured. The results show that even though kernel size (100-grain weight) is occasionally implicated when analyzing ear size and kernel position effects, the later two parameters have proved to have much more pronounced effects on grain germination and vigour parameters. The results show that kernel size

Table 4: Correlation analysis results of maize grain germination and seedling growth parameters under influence of size of ears and kernel position

	100-grainwt	Germination Capacity	Mean germi-nation time	Shoot length	Root length	Seedling dry weight
100-grain weight	1.00					
Germination capacity	0.20	1.00				
Mean germination time	0.27	-0.74**	1.00			
Shoot length	0.19	0.97**	-0.73**	1.00		
Root length	0.44	0.81**	-0.45	0.79**	1.00	
Seedling dry weight	0.56*	0.83**	-0.47	0.80**	0.82**	1.00

* = Significant at $P \leq 0.005$ ** = Significant at $P \leq 0.01$ n = 15

was only significantly correlated with seedling dry weight ($P \leq 0.05$) among the parameters measured. Germination capacity of kernels, in the contrary, was for example significantly correlated with MGT, shoot and root lengths and seedling dry weight. Correlation with MGT was negative, showing that grains with high germination capacity were also more vigorous. Correlation with the other parameters was positive thus also showing complimentary effects. Correlation between MGT and seedling shoot length was also significant and negative, also showing complementary trends ($P \leq 0.05$). Of the other parameters significant correlations are as indicated in the table. Generally, any significant effects on one parameter were also associated in a complementary trend with effects on the other parameters.

CONCLUSION

In terms of grain quality it has been evident that both selection of ears and discriminative threshing can be important criteria in improving quality of maize grains. Farmers who can afford this practice can have advantages that can likely be extended up to yield. That improved germination and vigour in grains and seedlings is assurance of better subsequent yields are a great incentive favouring such practice. There are still, however, some questions yet un-resolved. For example, there is need to investigate relationships of kernel position on ears with microbial and insect pest infestations of the grains, which may also account on quality; and whether presence of husks or de-husking may also influence quality of the grains.

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