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Germination of Corn (*Zea Mays* L.) Cultivars Seed and Its Relationship to Field Performance under Semi - Arid Conditions

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Abstract: *This study intended to evaluate seed vigour of Hybrid maize and cultivars under semi arid conditions in Sudan. Two experimental were conducted.* ***.*** *First one laboratory tests involved standard germination, speed of germination, seedling fresh and dry weights, shoot and root lengths, and electrical conductivity. The second one was field emergence, to assess speed of emergence, seedling fresh and dry weights, shoot and root lengths, and number of leaves. The laboratory tests was laid out as completely randomized and randomized complete block design for field emergence.(LSD) least significant differences and Correlation relationship was analyzed between the above tested values and vigour performances evaluated. The results showed that there was a significant difference among the cultivars in the above tests, and they were all suitable to evaluate seed vigour of maize seed. Germination percentage showed consistently close relation with field emergence, thus it was found to be the best indicator of field emergence in maize seed germination under semi - arid conditions.*

Keywords: Maize Seed, Germination, Vigour test, Semi arid, E.C, Field emergency.

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I. Introduction

Maize (*Zea mays* L.), known in USA as corn, is the third most important crop after wheat and rice in the world and grown in many countries over the world [1]. In Sudan, maize is grown mainly for human consumption. It is consumed as green maize fresh on the cob, or is baked, boiled or roasted. The grain can also be dried, ground and boiled into porridge or fermented into beer [2]. Moreover the need to avail more food is necessary with the observed increase in Sudan population. Sorghum, wheat and millet constitute the main staple food crops for people in the country [3]. Food shortage may sometimes arise due to erratic rainfall or bad weather, maize as a promising cereal crop, can safely participate in alleviating the problems of food shortages. Being a high yielding cereal, maize can assist in solving hunger and malnutrition crises for the inhabitants of conflict areas. Maize is also a good fodder crop that can contribute in solving the scarce fodder supply for the huge animal herds in Sudan, in addition to its multi industrial uses [4].

In addition, maize is used as a forage crop in dairy farms, because it is a good source of carbohydrates, besides, it contains almost 7.7% crude protein, 4.6% digestible protein, and 55.2% total digestible nutrient elements [5]. Maize can also be used as good silage due to the high ratio of sugars contained in maize silage such as dissolved sugar (62.8%) and ashes 2.6%, [4]. Although maize has long been considered a minor crop and grown mainly under rain-fed conditions in Kordofan, Darfur areas in the Northern states, recently, more attention has shifted towards the crop. Expansion has been noticed under the Gezira Irrigation Scheme - Blue Nile and White Nile Schemes under various governmental projects [6]. The increasing demand for maize for poultry feed or intermediary products for human nutrition have led to greater interest in this crop in Sudan [6].

Quality maize seed availability is required for sowing to ensure successful crop establishment, but non availability of such seeds is a limiting factor in boosting some countries maize production. Seed vigour is the most acceptable form for evaluating seed quality. It has been defined as the sum of properties that determine the activity and performance of seed lots of acceptable germination in a wide range of environments [7]. 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 [8]. It is therefore a comprehensive characteristic that is an important index of seed quality and is closely correlated with field performances.

Since the deterioration of stored seed is a natural phenomenon and the seeds tend to lose viability and vigour even under ideal storage conditions, it follows that the rate of seed deterioration varies greatly from one species to another and even among varieties of the same species [9]. The performance capabilities of many seeds deteriorate due to variations in temperature, relative humidity and moisture content in storage [10]. Moreover, field performance of maize may be influenced by many internal and environmental factors; the most important of these internal factors being seed vigour [11].

Seed vigour may influence crop yield through both direct and in direct effects; the indirect effects include those on percentage emergence which influence yield by altering plant population density and spatial arrangement; whilst direct effects are those on emergence rate which influence seedling vigour and uniformity. However, it is important to study seedling emergence and growth to understand seedling survival and recruitment. It was well established that high seed vigour can enhance seedling size via improving seed germination rate [12][11].

High seed and seedling vigour are required for a good stand establishment and successful crop performance in maize [13]. Vigorous seeds will produce excellent emergence and stand in proper soil environment; thus, it can improve the chances for satisfactory emergence.

Maize has very specific water and climatic condition requirements in order to thrive. Most importantly, for the plant to germinate it needs suitable temperature ranging from 15 to 20ºC [3]. The rapid and synchronous germination rate as well as good field establishment will be characteristic of vigorous seeds.

Seed test is an important parameter to assess the seed vigour. Standard germination, field emergence, shoot and root length, fresh and dry weight and electrical conductivity are good vigour tests for various crop seeds including maize in Sudan. These tests are rapid, inexpensive, simple and useful for many crops, and seed vigour has also shown a good correlation with stand establishment in maize [4].

Field emergence percentage and field emergence speed are the most direct indicators for seed vigour. Field emergence percentage is the only index in most reports about seed vigour evaluation, whereas field emergence speed has often been ignored [14][15][16][17]. The current study, therefore aimed at evaluating the seed vigour and its relationship to field emergence in selected maize varieties under semi- arid conditions of Sudan. The specific objectives were as follows: To evaluate (in the lab) the seed vigour of four maize hybrid cultivars seed samples; to evaluate the field emergence of the seed samples of the four maize hybrid cultivars; and, to establish the relationship between seed vigour and field emergency of the four hybrid cultivars.

II. Material And Methods

An integrated field and laboratory experiment approach was employed to evaluate seed vigour/quality in maize hybrids. The experiments were carried out at the experimental farm (Latitude 15̊ 40 N, longitude 32̊ 32 E) and the University of Khartoum laboratory, Shambat.

Study site

Field trials were conducted during 2013-2014 summer seasons under the rain-fed conditions. The farm has heavy clay (more than 50% clay content) and alkaline (pH 8.5) soil. The study area falls in the arid climatic zone of the Sudan just to the south of the fringes of the semi-desert climatic zone. The arid climate is characterized by summer rains and warm winters. The main annual temperature is 29.9 ºC. Average maximum temperature in the hottest months (April-June) is 41.2ºC while the average minimum temperature for the same period is 6.3ºC. The average minimum temperature during the winter (Dec-Feb) is 16.5 ºC. The relative humidity fluctuates during the day (GMT) and the year (season). The mean annual relative humidity ranges between 26 -21 % (Jan to Feb), 15 -26 % (March to June) and 41-48 % (July to September, the wettest three months). The average annual rainfall is about 121mm falling mainly in July and August with lower amounts in September. The rainfall is erratic in quantity, intensity and distribution. The high temperature coupled with strong solar radiation result in values of potential evapotranspiration exceeding by far the rain fall almost throughout the year, except in July, August and September. This is not unexpected under the semi desert climate prevalent in the study area [18].

Materials

Seeds of five maize varieties, namely; Hudeba one (H1), Hudeba two (H2), Simon, Bolson and AS 71, were used in the tests. Seeds for the two open pollinated cultivars (H1 and H 2) were provided by Arab Sudanese Seed Company. The other three cultivars are hybrids introduced to Sudan from Turkey, and were provided by Pollen Seed Company. We conducted different laboratory and field emergence tests to evaluate maize seed vigour of these cultivars. The tests were carried out at the University of Khartoum laboratory, Shambat, Khartoum, Sudan.

Methods
Experimental design
The experiments were laid as Randomized Complete Block Design RCBD with 5 treatments replicated 4 times in both field and laboratory experiments.

Methods
Laboratory tests (seed quality parameters conducted)
These involved the standard germination, speed of germination, seedling fresh and dry weight, seedling growth rate, shoot and root length, and electrical conductivity tests. It was laid out as randomized complete design in four replications; two hundred seeds from each cultivar were divided into four replicates, the test referred to the international Seed Association rules for seed testing [19]. Seed were placed in pots, and incubated at 20± 1°C, for 16 days in germination room in the laboratory at department of Horticulture. Numbers of germinated seed were recorded, through daily count and the final germination percentage was calculated at the end of the test for each cultivar.

Speed of germination test
This test conducted based on the following formeukar:

$$X = \frac{\text{Number of normal seedlings}}{\text{Day of the first count}} + .. + \frac{\text{Number of normal seedlings}}{\text{Day of the final count}}$$

Seedling fresh and dry weight
Seedling fresh and dry weights were assessed after the final count, the seedlings were washed with distilled water and weighed, and fresh weight was recorded to the nearest gram respectively. Seedlings were placed in to envelopes and dried in an oven at 75±1̊c for 24 hrs. The dry weight was recorded.

Seedling growth rate
It was calculated after the seedling dry weight had been determined. Seedling growth rate was computed using total dry weight of normal seedlings weighed, and divided by the number of normal seedlings, by the following formula:

$$\textit{Seedling growth rate}\ (\mathrm{Gr}) = \frac{Y}{X - (a + b)}\ \textit{mg/normal seedling}$$

Where:

X = Number of seeds germinated
a = Number of abnormal seedlings
b = Number of dead seeds
X – (a + b) = Number of normal seedlings
Y = Total dry weight of normal seedlings (mg)

Seedling shoots and root length
This test was measured. Shoot and root length from the point of attachment to the cotyledon above the soil to the tip of the seedling and root, respectively. The average shoot and root length was calculated by dividing the total length by the number of normal seedlings measured.

Electrical conductivity test
The EC test was conducted on four replicates of 50 seeds each for each treatment. The test referred to the international rules for seed testing [19]. EC was tested and the leachate conductivity was measured in mmhos/cm/g using a conductivity meter (Shambat, Khartoum, Sudan) at soil department. (Konductometer Schott - Gerate GMBH, Hofheim, Germany).

Field emergence test and observations made
This test was conducted based on International Seed Association rules [19] method; 200 seeds divided in to four replications, with each replicate containing 50 seeds. Seeds were sown on 17th of March 2013, at a depth of 3 cm with 20 cm in-row and 20 cm inter-row spacing. The irrigation interval was three days, and daily seedling emergence counts were recorded. This was carried out when the seedling's leaf tip/blade just appear above the ground surface, and continue until there was no new emergence. Field emergence %, speed emergence, fresh and dray weights, shoots and roots length, and numbers of leaves were observed.

Statistical data analysis

Data obtained from the different tests were subject to statistical analysis, and mean separation was performed using the least significant method (LSD) at $P \leq 0.05$ to evaluate the differences vigour among the different hybrid seeds and cultivars [20].

III. Result

This part of the paper presents the finding of the research which conducted in the laboratory and field experiment.

Laboratory tests results

Results show that there were highly significant differences among the cultivars. The mean germination percentage for the five cultivars in the first day ranged between 46.7 and 1.8%**,** were the AS71 recorded the highest germination percent 46.7%, while H1 and H2 had the lowest germination percent 1.8% (Table 3.1

Speed of germination test

Analysis of variance showed there were no significant differences between cultivars for speed of germination. The highest speed of germination was recorded by H 2 (5.6 days) and the lowest speed of germination was recorded by booth AS71 (5.0 days), and Bolson (5.0 days), (Table 3. 1).

Final germination

Analysis of variance shows there was no significant difference among the cultivars (Table 3.2). Bolson had the highest germination (98.0%), while Simon recorded the lowest germination (90.5%).

Effect of cultivars on seedling shoots and roots length

Results show that there were significant differences among the cultivars for shoot length. The highest shoot length was recorded by Simon (26 cm) and the lowest shoot length (23.1cm), was recorded by H 1, (Table 3. 3).The results of seedling root length indicated highly significant differences between cultivars. The highest root length was recorded by H1 (27.5 cm) the lowest seedling root length recorded by Simon (23.3 cm) (Table 3.3).

Seedling fresh and dry weight

Seedling fresh weight showed significant differences among the cultivars. Seedling fresh weight ranged from 87.3 g to 69.15 g (Figure 3.1). The highest seedling fresh weight was recorded by Simon (87.3 g), and the lowest recorded by AS71 (69.2 g). Moreover analysis of variance showed highly significant differences among the cultivars for seedling dry weight. Seedling dry weight ranged from 11.2 g to 8.7 g. The highest seedling dry weight was observed by Bolson (11.2 g), and the lowest was recorded by H1 (8.7 g).

Table 3. 1Percentage of seed emergence observed by number of days

Cultivar	1st day	2 nd day	3rd day	4th day
Simon	37.3	72.2	74.2	74.9
AS71	46.7	78.3	83.1	85.1
Bolson	32.7	80.9	86.5	86.5
H2	1.8	42.9	69.9	76.6
H1	1.8	59.1	78.7	83.1
Mean	24.1	66.7	78.4	81.2
LSD (5%)	5.6	14.5	7.5	7.5

Note: Data are means of four replications

Table 3.2 Effect of cultivars on final seed germination percentage (laboratory test)

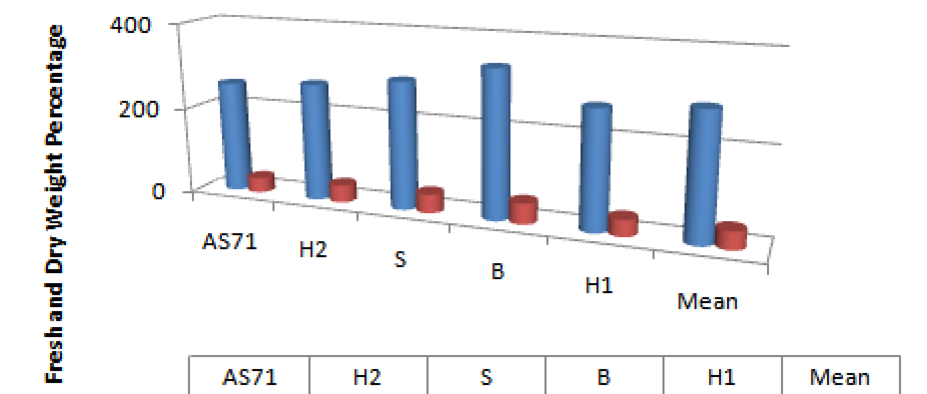
Cultivars	Germination %
Simon	90.5
AS71	96.5
Bolson	98
H2	91.5
H1	95
Mean	94.3
LSD (5%)	4.6

Note: Data are means of final percentage

Table 3.3Effect of cultivars on seedling shoots and roots length (Lab test)

Cultivars	Mean shoot length (cm)	Seedling root length (cm)
Simon	26	23.3
AS71	24.8	24.9
Bolson	25.7	24.4
H2	24.6	24
H1	23.1	27.5
Mean	24.8	24.8
LSD (0.05)	1.9	1.9

Note: Data are percentage shoots and roots length.



	AS71	H2	S	B	H1	Mean
Fresh weight (g)	257	269.7	292.6	337.4	268.9	285.1
Dry weight (g)	34.1	39.9	43.4	47.8	37.9	40.6

Fig 3.1 Effect of cultivars on seedling fresh and dry weight (lab test).Note: Seedling fresh and dry weight (grams)

Field emergence tests

Analysis of variance shows significant differences among the cultivars for field emergence. The mean percentage between the cultivars ranged between 55.4% and 33.8% for the first day. Bolson recorded the highest emergence (55.4%), and H2 had the lowest emergence (33.8%). However differences for emergence percentage between the cultivars were not significant for the 2nd day and afterward (Table 3.4).

Speed of emergence field tests

Analysis of data showed no significant differences between cultivars for speed of emergence in the field test. The highest speed of germination was recorded by H 2 (5.8 days) followed by H 1 (5.7 days), followed by Simon (5.4 days), and AS71 (5.4 days), the lowest speed of emergence was recorded by Bolson (5.3 days), (Table 3. 4).

Table 3.4 Means of four days emergence and speed of emergence (field test)

Cultivars	1stday	2 nd day	3rd day	4th day	Speed of field emergence (days)
AS71	52.8	75.7	81.5	84.2	5.4
H2	33.8	66.8	73.8	75.9	5.8
Simon	53.4	77.2	80	80.7	5.4
Bolson	55.4	73.9	81.5	81.5	5.3
H1	36.5	68.9	80.5	80.5	5.7
Mean	46.4	72.5	80.1	80.6	5.5
LSD (0.05)	14.1	n.s	n.s	n.s	

Note: Data are means of emergence and speed of emergence %

Number of leaves per seedling

The number of leaves per seedling for the cultivars ranged between 6.6 and 5.8 leaves with highly significant differences between the cultivars, (Table 3.5). H2 recorded the highest number (6.6), and Simon recorded the lowest number of leaves (5.8).

Seedling shoots and root lengths

Results show there was no significant difference for shoots length between the cultivars. The highest shoot length was recorded by Bolson (36 cm), H1 had the lowest shoot length (33.4 cm).Moreover Seedling roots length was significantly different among the cultivars. The highest root length was recorded by Bolson (21.3 cm) and the lowest shoot length recorded by H2 (15.8 cm) (Table 3.6).

Seedling fresh and dry weight

Seedling fresh weight showed no significant differences among cultivars. The highest percentage among the cultivars were recorded by Bolson (337.4 g), and the lowest percentage was recorded by AS71 (257 g) (Table 3.7). Moreover analysis of variance showed no significant differences for seedling dry weight between the cultivars.. The highest dry weight was recorded by Bolson (48g), were the lowest was recorded by As71 (34.1g) (Table 3.7).

Electrical conductivity (EC) test results

Result shows there were significant differences among the cultivars for EC test, ranged between 0.2 and 0.1mmhos/cm/g of seed. (Table 3.8).

Table 3.5 Effect of cultivars on number of leaves per seedling

Cultivars	Number of leaves
AS71	5.9
H2	6.6
S	5.8
B	6.1
H1	6.1
Mean	6.1
LSD (0.05)	0.3

Note: Data are mean percentage of seedling leaf number

Table 3.6 Effect of cultivars on seedling shoot and root length (field test)

Cultivars	Shoot length (cm)	Root length (cm)
AS71	34	20.6
H2	34	15.8
S	35.3	19.8
B	36	21.3
H1	33.4	16.3
Mean	18.7	18.7
LSD (0.05)	n.s	4

Note: Data are percentage of shoots and root length. Note; ns, not significant.

Table 3.7 Effect of Cultivars on seedling fresh and dry weight (field test)

Cultivars	Fresh weight (g)	Dry weight (g)
AS71	257	34.1
H2	269.7	39.9
S	292.6	43.4
B	337.4	47.8
H1	268.9	37.9
Mean	285.1	40.6
LSD (0.05)	n.s	n.s

Note: Data are mean percentage fresh and dry weights.
LSD: Least significance differences
n.s: no significant differences

Correlation coefficients analysis

Correlation coefficients between standard germination shoot length, root length, fresh weight, dry weight, and field emergence showed that final germination percentage was positively correlated with field emergence (Table 3.9). Linear correlation coefficient studies showed negative correlation between shoot length in the Laboratory and field emergence test. The correlation coefficient result showed that root length in the Laboratory was positively significantly correlated with field emergence. Seedling fresh weight in the Laboratory and seedling fresh weight in the field test was negatively correlated with field emergence linear correlation coefficient relationship between field emergence and electrical conductivity showed positive correlation (Table 3.9).

Table 3.8 Effect of cultivars on electrical conductivity (EC)

Cultivars / water	Ec (mmhos/cm/g)
Wt	0
AS71	0.1
H2	0.1
S	0.1
B	0.2
H1	0.1
Mean	0.1
LSD (5%)	0.2

Note: Wt. means water , Ec. Electrical Conductivity

Table 3.9 Correlation coefficient between field emergence and germination attributes

Parameter	Field emergence
Final germination	0.799241 ns
Seedling fresh weight	-0.4509 ns
Seedling dry weight	-0.03055 *
Seedling shoot length	-0.00665 ***
Seedling root length	0.392628 ns
Electrical conductivity	0.516181 ns

Note: ns. No significant differences
*Significant differences
**Highly significant differences

IV. Discussion

A result shows highly significant differences among the cultivars in laboratory test, for the standard germination. This result agrees with the findings of [21] in ryegrass. For seedling dry weight larger seeds produced more dry weight compared with smaller seeds. These results supported by the previous finding of [22] in sunflower. A positive correlation was found between seedling dry weight and field emergence in mungbean (Vignaradiata [C]) by [23]. Most small seeded cultivars possessed longer shoot and root length compared with the large seeded cultivars and this could be explained by faster imbibitions and germination. This trend was maintained during the early seedling development (4 - 20 days after germination). The reduction in shoot and root length was found to be influenced by the age of seeds. Similar trend was observed by [24] in aged groundnut. Result of seedling shoot length showed there were no significant differences among the cultivars. However seedling root length showed significant difference among the cultivars. Moreover field emergence test analysis of variance showed a significant difference between the cultivars. Number of leaves in field emergence indicates a highly significant difference among the cultivars this result similar to previous research finding by [25] in soybean, found that strong normal seedling was highly correlated with standard germination test, but correlated to a lower degree with field performance and highly correlated with the yield. Similarly vigor classification test correlated better with field emergence under stressed conditions than any single laboratory test, finding by [26] in soybean. Seedling fresh and dry weight showed no significant different among the cultivars. For electrical conductivity results show significant differences among the cultivars, the highest recorded by Bolson (0.2 mmhos/cm/g).This results agrees with previous research by [27] in cotton seed. The higher release of electrolytes from large seeded cultivar could be attributed to higher amount of food reserve and availability of greater organic and inorganic metabolites. Were the lower conductivity recorded by AS71, S, HI, H2 respectively (0.1 mmhos/cm/g) This result supported by [28] who reported that in soybean, the smaller seeds which maintained the higher germination percentage showed lower conductivity reading indicating high seed quality. More over Happ et al. (1993) indicated that an increase in leachate of electrolytes from weak, deteriorating and dead ryegrass seed results from degradation of cellular membranes and increased cell membrane permeability. Simple correlation showed that final germination percentage was positively correlated with field emergence. Moreover correlation between field emergence and seedling shoot length showed negative result between Lab test and field emergence. Seedling root length in the laboratory test was positively correlated with field emergence. This result agrees with [29] who found that shoot length and root length were highly correlated with each other and root length was positively correlated with the field emergence.

Correlation coefficient results indicated that seedling fresh weight in the Lab was negatively correlated with field emergence. Moreover seedling dry weight in Lab was negatively correlated with field emergence. These results contradict with [30] found that seedling dry weight among the best single tests in predicting seedling emergence in wheat. Linear correlation between field emergence and electrical conductivity showed positive result. This result supported by finding with [31] and[32] in Faba bean and peas, respectively.

V. Conclusion

In conclusion the standard germination, shoot and root length, fresh and dry weight, leaf number and electric conductivity were all suitable to evaluate seed vigour of maize under semi arid condition for the five promising cultivars of maize. Result showed that there was significant difference in germination percentage among the cultivars both in the laboratory and in the field tests , speed of germination was highly significant in hybrids cultivars than open pollinated cultivars, moreover result showed that there was no significant differences in seedling growth (shoot and root length, fresh and dry weight) were recorded among the cultivars, but there was high positive correlation between germination percentage and field emergence, showing that germination percentage could reflect field emergence of maize cultivars under semi- arid conditions Correlation coefficient showed that germination percentage could be the best suitable test using to assess field emergence under semi-arid conditions.

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