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Research Application Summary

Foxtail millet as a new crop in Namibia: Varietal seed differences in germination

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Abstract

Time of planting is a critical agronomic precedent to success or failure of a crop in the field. Any delay can drastically reduce yield or completely fail a crop given the influence of incongruent environmental factors such as temperature, moisture, oxygen, light and other factors that may bear on the extent of germination and seedling emergence. Emphasis is in effect often given to high-quality seed that has excellent genetic potential and good germination and vigorous seedling growth. In North Central Namibia where the seasonal summer rainfall on the highly sandy soils is variable, unpredictable and/or poorly distributed, early phase of growth starting at germination presents a major emergence and pre-anthesis challenges. Many farmers in this region are usually wary to sow seed even with the most trusted adapted pearl millet crop (*Mahangu*) until they are fairly sure that sowing time is promising. When not, most local farmers without irrigation options tend to abstain from sowing until the sandy soils are moist. From this study, indications are that any introduction work with foxtail millet [*Setaria italica* (L.) P. Beauv.] as a new crop into a new region ought to be superseded by germination trials in order to adjust for seeding rates, but this must be done in connection with a sowing time that is supported by adequate soil moisture on a sandy soil.

Key words: Environmental factors, Mahangu, Namibia, *Setaria italica*

Résumé

Le temps de la plantation est un précédent agronomique essentiel à la réussite ou l'échec d'une culture dans les champs. Tout retard peut réduire considérablement le rendement ou échouer complètement une culture étant donnée l'influence des différents facteurs environnementaux tels que la température, l'humidité, l'oxygène, la lumière, et d'autres facteurs qui peuvent influencer l'étendue de la germination et la levée des semis. L'accent est en effet souvent mis sur des semences de haute qualité qui ont un excellent potentiel génétique, une bonne germination, et une croissance vigoureuse des semis. Dans le nord centre de la Namibie où la pluviométrie estivale saisonnière sur les sols très sablonneux est variable, imprévisible et / ou mal répartie, la phase initiale de croissance à partir de la

germination présente une émergence importante et les défis pré-anthèses. De nombreux agriculteurs de cette région sont généralement méfiants à semer même avec la culture adaptée la plus fiable du millet perlé (Mahangu) jusqu'à ce qu'ils soient assez sûrs que l'époque des semis est prometteuse. Lorsqu'ils ne le sont pas, la plupart des agriculteurs locaux sans option d'irrigation ont tendance à s'abstenir de semis jusqu'à ce que les sols ~~sableux soient humides. De cette étude, il semble que les travaux de mise en place avec le~~ Panis [*Setaria italica* (L.) P. Beauv.] en tant qu'une nouvelle culture dans une nouvelle région doit être remplacée par des essais de germination afin d'ajuster les taux de semis, mais cela doit être fait en relation avec un temps de semis qui est soutenu par l'humidité du sol adéquate sur un sol sablonneux.

Mots clés: les facteurs environnementaux, Mahangu, Namibie, *Setaria italica*

Background

To expand its cultivation in Africa, Chinese millets have been tested in Uganda and Ethiopia, and are receiving attention for introduction into Namibia as a new crop since they are considered high drought endurance. In retrospect Zhangjiakou Academy of Agricultural Science (ZAAS) in China is collaborating with UNAM to field evaluate ZAAS hybrid lines as a new crop to supplement Mahangu which is the most pervasive staple cereal grain in Namibia. In the Chinese visionary view, foxtail millet has been described as: *"Hope for Dryland Agriculture; Good news for poor peasants"*. Among others, the hybrids are said to have proven advantages of possessing heavier ears and longer seed heads (up to 30-50 cm long); higher hybrid yield (40% higher > unimproved cultivars); better grain quality with good taste and rich in nutrition quality; and above all, are drought enduring. These attributes are of high relevance to Namibia's agronomic interests (ZAAS Monograph, 2011).

Literature review

Foxtail millet [*Setaria italica* (L.) P. Beauv.] is summer cereal crop cultivated worldwide and since ancient times in China (Lu *et al.*, 2009; Diao, 2011) but new to Africa (Austin, 2006; Baltensperger, 1996a; Baltensperger, 2002b). Outside Africa, it ranks second in the world's total production of millets (Marashee, 1993). It is consumed in Asia due to its ability to compensate for the nutrient deficiencies of rice, i.e., lack of vitamins and minerals (Soh *et al.,* 2002).

Crop seed for sowing the next crop are vulnerable to attack by mold fungi. Several reports about seed-borne mycoflora on foxtail millet have been published (Erpelding and Prom, 2006; Girish, *et al*., 2004). Post-harvest fungal infection, according to farmers, is one of the key constraints for mass production of these grains. Germination tests are thus important for predetermining the probable success of stand establishment in the field; especially in less predictable fragile ecologies such as are found in North-Central-North Eastern (NCNE) Namibia (Andrew and David, 2009). The tests are also indicators of a number of phenomena which bear genetic relation to seed dormancy, storability and oligosaccharide content.

Zhao Jia and Zhou Zhihai (Pers. Comm.) in addition have also observed that lower germinations in foxtail millet can be expected due to up to 30% seed sterility.

To support foxtail millet varietal introduction (FMVI) research, ancillary laboratory seed germination studies were undertaken at University of Namibia with the two objectives in mind. These were to investigate differences among: 1) Nine hybrids; and 2) F_1 ('mother' seed produced in China) and F_2 ('baby' seeds grown at Ogongo, Namibia from the F_1s); respectively. This was with a view to relating some of cases of non-uniform field stands previously observed across plots within and among the various trial locations.

Materials and method

The *in vitro* experiment was conducted at the Department of Crop Science, University of Namibia, Ogongo Campus. The F_1 hybrid seeds (2013-China acquisitioned) (from which F_2s were subsequently obtained) were grown under the Ogongo-Namibia conditions. The seeds had been stored in a refrigeration cooler set at 4 ^{0}C during the previous year before undertaking the seed germination test. One hundred seeds of each hybrid variety (both as a pair of F_1 and F_2) of the foxtail millet were used.

A pilot study was undertaken in 2015 on seven hybrid seeds of which hybrid pairs were labelled as 'baby' (i.e. F_2 seed raised under Ogongo conditions) and 'China' (F_1) seeds supplied by ZAAS. The 2015 study involved V1 pair, V2 pair, V3 pair, V4 pair, V5 pair, V9 pair and V11 non-pair (i.e. F_1. During the 2016 study, the V8 pair and E8 were included but not the V11. Before the *in vitro* germination, seeds were disinfected in 0.02% Sodium hypochlorite (NaOCl) solution to clean them and prevent them from any fungal contamination, and then shaken in 25 mL of distilled water prior to placing them in the petri dishes. The seeds were germinated on a top moist paper (Whatman Grade 181) in a 9 cm diameter petri dish at the rate of 100 seeds per petri dish. Each plate was moistened with 4 mL of distilled water. They were germinated at 20^0 C (at room temperature) for 12 hours in the daylight and moved into the incubator for 12 hours at 30^0 C. Germination was considered present when the radical protruded by 2~4 mm. The % germination was calculated and recorded on a daily basis usually in the evening before placement in the dark exposure.

A completely randomized design with three replications was used in this study. Eight different hybrid seed sources were used in the experiment. The germination tests and recording started on Day 4 in the pilot study of 2015 when germination was observed and terminated at Day 8. In the 2016 experiment, germination occurred at Day 3 and was evaluated up to Day 8 to align the data period with the previous study.

Results

A sample of the germination tests are shown in Figure 1. On a daily basis observations of germinated seeds were immediately counted and removed from the petri dishes and the remaining seeds re-watered for next day observation. The petri dish on the bottom left with elongated seedlings was the control in which seeds were allowed to extend longer than the

Figure 1. ***In vitro*** **germination tests (2015 and 2016) conducted over an 8-day period in Ogongo Campus lab at the University of Namibia.**

recording period. On pairing both the F_1 (from China), and F_2 (Ogongo baby seed raised from F_1) there were considerably differences as demonstrated by the bars (Fig. 2).

Four varieties showed a high germination % in F_2 generation (seed raised at Ogongo) than in F_1 generation (seed raised in China); with V9 F_2 showing the highest (63%) germination amongst all tested. On the other hand, two China-produced varieties (i.e., V1 and V2) showed the F_1 with higher germination than for F_2 from Ogongo at 43% and 46%, respectively.

In the 2016 test, results obtained were manually clustered into four categories (Figs. 3-6). In these cases highest germinations were at Days 3 and 4 followed only by sporadic germinations occurring between Days 5 and 8.

Day by day germination trends. For category 1, $V4F_2$ and $V3F_1$ recorded the highest germination on Day 3 (between 44 and 45%). However, the former added another 27% on Day 4 while the latter, added only 9%. $V2F_2$ had about 22% on Day 3 and a similar % on Day 4. Thereafter, germination percentages were equally very small and sporadic.

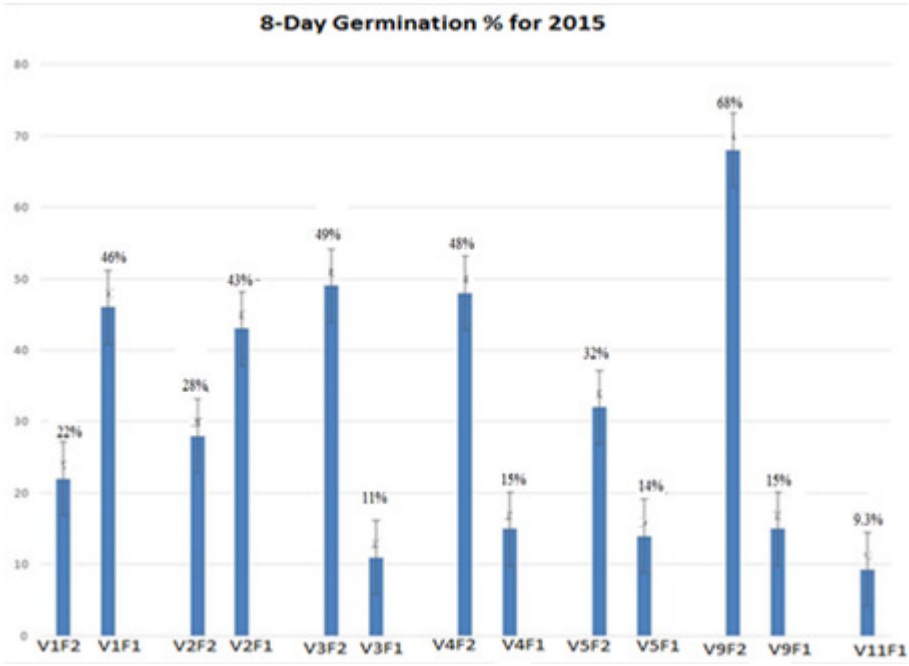

Figure 2. *In vitro* germination Pilot tests (2015) conducted over an 8-day period in Ogongo Campus lab at the University of Namibia

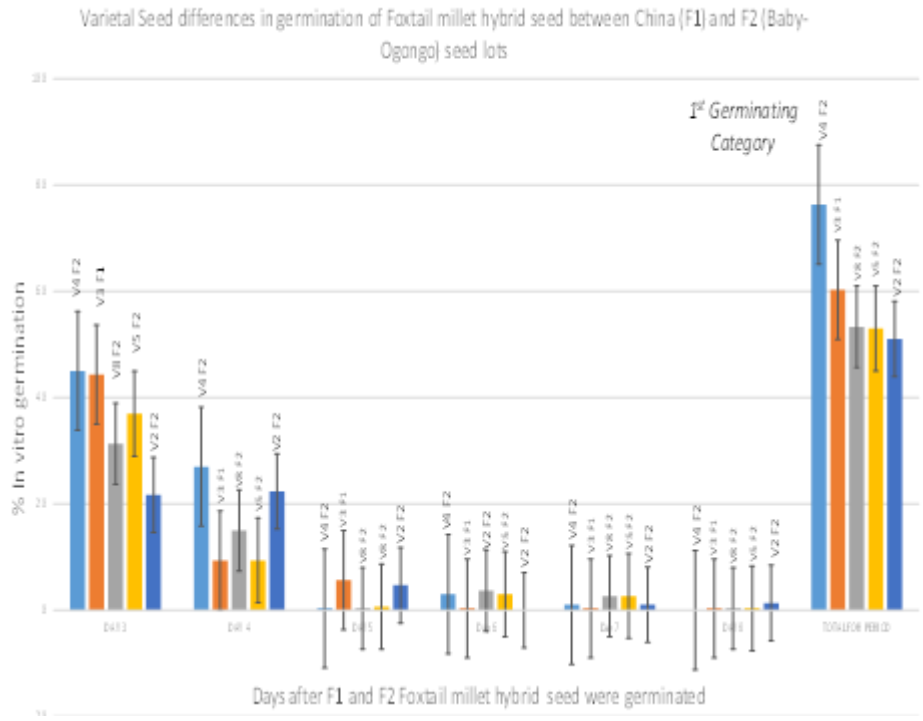

Figure 3. A cluster of varieties with greater than 50% *In vitro* germination (total) conducted in (2016) over an 8-day period in Ogongo Campus lab at the University of Namibia

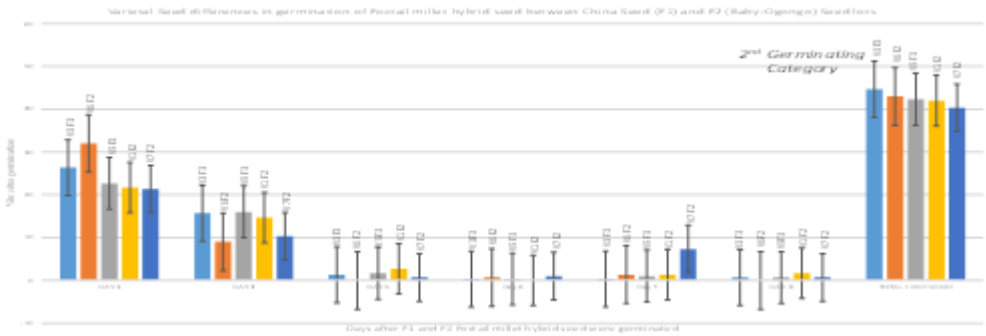

Figure 4. A cluster of varieties with *In vitro* germination (total) between 40% and 45% conducted in (2016) over an 8-day period in Ogongo Campus lab at the University of Namibia

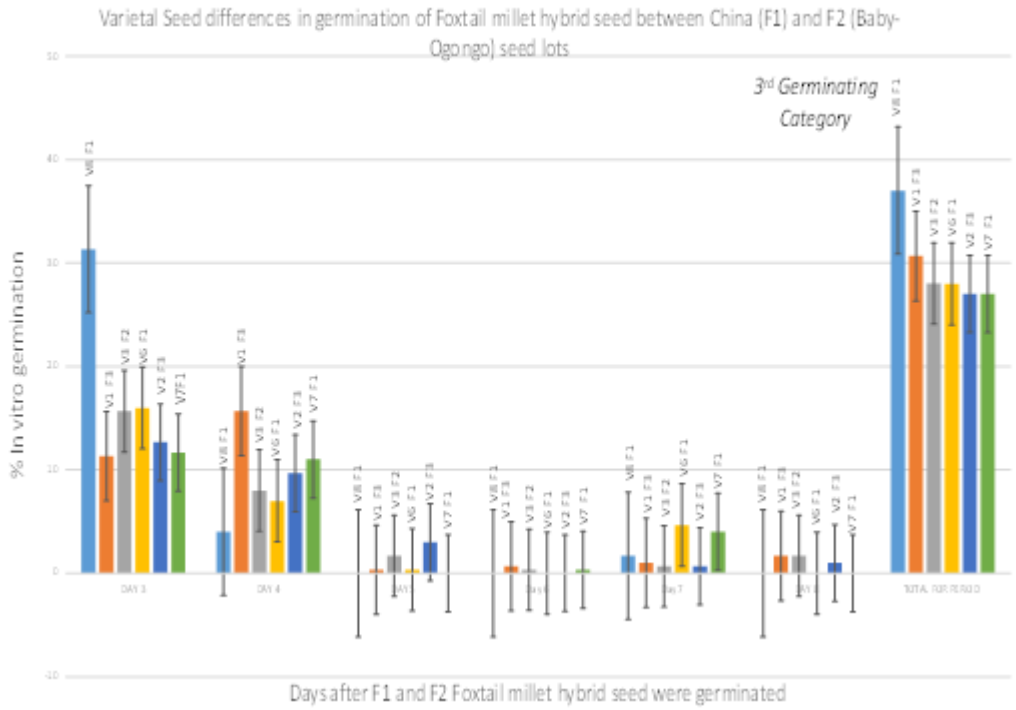

Figure 5. A cluster of varieties with *In vitro* germination (total) between 27% and 37% conducted in (2016) over an 8-day period in Ogongo Campus lab at the University of Namibia

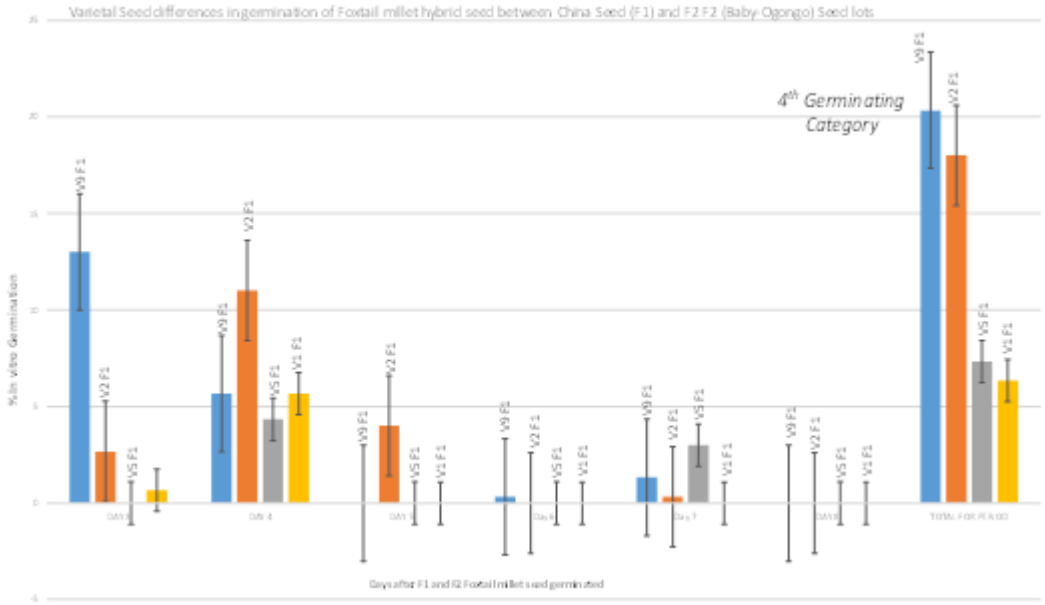

Figure 6. A cluster of varieties with *In vitro* germination (total) less than 20% conducted in (2016) over an 8-day period in Ogongo Campus lab at the University of Namibia

In the 2nd Category (see Fig. 4), a similar trend to Category 1 was observed with a declining trend in subsequent days. However, V6 F_2 had a 32% germination at Day 3 but declined at Day 4 with only a 9% additional germination. In Figure 5 (Category 3), $V8F_1$ had 31% germination higher than the rest but declined at Day 4, whereas the rest $V1F_3$, $V3F_2$, $V6F_1$, $V2F_3$ and $V7F_1$ had between 7 and 16% higher additional germination compared to V3 F_1 with 4%. Like the foregoing Categories, Day 5 to Day 8 had sporadic and reduced additional daily germinations. In Figure 6 (the lowest germinating Category), $V9F_1$ at Day 3 and V2 F_1 at Day 4 had germinations of 13 and 11% respectively, higher than the rest. In terms of total germination over the study period, $V4F_2$ in Category 1 had the highest germination (76.3%) followed by $V3F_3$ in Category 2 (45%).

Comparisons amongst generations. Data seems to indicate that F_2s appeared more frequent than F_1s in the higher Category. In the latter Category, four varieties; namely: $V4F_2$, $V8F_2$, $V5F_2$ and $V2F_2$ were frequent. $V3F_1$ appeared only once.

In Category 2, four varieties; namely: $V1F_2$, $V6F_2$ and $V7F_2$ appeared 3 times as is obvious, while $V3F_3$ and $V9F_3$ appeared twice. In this Category the above are Ogongo baby seeds. The 2nd lowest germinating Category 3 had the following occurrence frequency; namely: $V1F_1$, $V6F_1$ and $V7F_1$ appearing 3 times, $V3F_2$ (once only), and $V1F_3$ and $V2F_3$ appearing twice. From these data, more of the China-sourced seed seem to have suffered lower *In vitro* germinations.

In the 4th and lowest category, the frequency was as follows: V9F1, V2F1, V5F1 and V1F1 are all the China-sourced seeds which appear to support the observation stated for Category 3 and the results of 2015 except for V1 and V2 (see Fig. 1).

Discussion

The results for 2015 suggest that a non-perfect match between F1 and F_2 could be due to either seed lot or filial variation. Seed lot differences are generally environmental, while filial differences are due to whether or not F_2 progenies segregated. In all instances, germination trends suggest that immediate germination tend to occur on 3rd and possibly on 4th day of planting. The first four days after the seed germinate is a critical consideration on the sandy soils typical of Ogongo, because it requires adequate rain or irrigation.

Results further suggest a high likelihood of the seed lot source effects. In other words, seeds that were produced from China had lower germination compared to the seeds produced in Ogongo. However, there was no Ogongo produced F_1 to compare with the China seed F_1. Similarly, comparisons are lacking between F_2 Ogongo-produced and F_2 China-produced which would have given a more realistic and meaningful comparison than this study suggests. Suffice it to state that F_1 crosses were exclusively supplied from China where the crosses were made but not in Ogongo. Thus, there seams to be no cosistent relationship between the F_1 and the F_2 germinations. The observation made earlier by our collaborators of a 30% sterility possibility does not seam to account for non-germinated seeds especially since germination failure was as high as 67% in some cases. Other factors may have affected the *In vitro* germination such as seed vigour, seed viability, seed lot, environment or laboratory conditions, among others.

Conclusions

From this study, indications are that any introduction work with foxtail millet as a new crop into a new region ought to be superseded by germination trials in order to adjust for seeding rates. However, in sandy soils this must be done in connection with a sowing time that is supported by adequate soil moisture.

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