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Indigenous Knowledge Coping Strategies against Hail Damage

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KEYWORDS Climate Change. Seed Selection. Local Farmers. Maize. Seed Quality

ABSTRACT The study investigated the effect of simulated hail damage on maize seed quality combining agronomy, laboratory analysis of seed quality and traditional knowledge of subsistence farmers. Three popular maize cultivars grown at two locations and farmer traditional knowledge about seed quality was determined at three different locations. The study found that there are significant genotype and site differences with respect to response to hail damage. Crop management manipulation by varying plant population was found to be important. The local knowledge of farmers correlated with scientific results of seed quality. Indigenous knowledge used in climate change adaptation included; changing the choice of crop and variety, planting, weeding and harvesting periods, shifting from rain-fed to irrigated agriculture and adopting tolerant and early yielding crop cultivars. The findings of this study can be used to relate traditional systems of maize production to select planting dates to mitigate hail damage effects of climate change.

INTRODUCTION

Climate change is a global challenge that does not only affect agricultural crop productivity but also affects indigenous people and practices in terms of poverty and food insecurity (Ngaira 2007; Dewi 2009; Nkomwa et al. 2014). The incidence of hail storms is likely to increase in the future due to global warming accompanied by considerable losses in agricultural crops (Botzen et al. 2010; Bore et al. 2011; Sisu et al. 2011; Zhao et al. 2012). Given the detriments from climate change, indigenous farmers have established various ways that they traditionally used to notice altered climate patterns. Their strategies include monitoring changes in the environment, tree growth, phenology, wind directions, moon and stars characteristics, diviners as well as particular animal behaviour patterns (Gyampoh et al. 2009; Egeru 2012; Elia et al. 2014). Observing these changes necessitated the need for adaptation strategies to climate change (Egeru 2012) which includes using indigenous knowledge (IK).

In order to cope with the detrimental effects of climate change the indigenous farmers have employed several strategies which include changing the choice of crop and variety (Nkomwa et al. 2014) as well as planting, weeding and harvesting periods in their agricultural management practices in addition to shifting from rain-fed to irrigated agriculture due to severe drought (Egeru 2012; Li et al. 2013). The crop cultivars that are mostly adopted are those that are tolerant to climate change induced conditions as well as those that are early yielding cultivars (Ishaya and Abaje 2007; Gyampoh et al. 2009; Nkomwa et al. 2014). All this indigenous intelligence supports the prevailing and increasing cognisance of indigenous knowledge and practices as a solution to sustainable and improved livelihoods for farmers and communities faced with the challenge of climate change (Achiando et al. 2010). Therefore, as reported by previous studies, it has been shown that IK may be an effective way of dealing with climate change (Gyampoh et al. 2009). Despite the success rate of indigenous knowledge system, more research is needed to determine resilience of maize cultivars to hail damage under different management practices such as environment and seed selection.

Past traditions coupled with present innovations, this knowledge system is not only important in informing and guiding scientific understanding but also in policy development so as to relate to local conditions (Sillitoe and Marzano 2009). However, though the system and practices are important in tackling the problems of the world including climate change, the following challenges are common barriers; new diseases, technologies, variable seasons, unpredictable climate events and social inclusion of younger community members with low or no adoption of indigenous knowledge practices (Egeru 2012; Rajasekaran 1993).

Maize (*Zea mays* L.) is among the world's leading staple and industrial crops after wheat (*Triticum aestivum* L.) and rice (*Oryza sativa* L.) (Omara 2013; Tenaillon and Charcosset 2011). In spite of the significant role maize plays in global trade and economy, it still faces various limiting factors to its production (White and Johnson 2003; Mirza 2003). As a summer crop, maize is prone to hail damage which naturally occurs during warm seasons. Hail induced plant injuries may be inflicted on the leaves, stalk, branches, or fruit (Lemons 1942). Hail damage typically results in significant leaf damage and abscission which translates to loss in leaf area. Thus, hail damage will result in reduced photosynthesis due to loss of leaf area. Not only does hail have deleterious effects on crop yield but also seed quality. The consumers are also implicated after a hail event as they have to pay higher prices for less marketable products of maize.

Seed quality is an important property of seed lots which is advantageous not only for the success of the crop but also the marketability, especially for seed industry (Milosevic et al. 2010). The attributes of seed quality are genetic, physical and physiological in nature. These include seed health, viability, vigour, shape and size (Kerr 2009; Bishaw et al. 2012; Tollenaar and Daynard 1987; Heidari 2012; Vasilas and Seif 1985; Vasilas and Seif 1986; Singh and Nair 1975; Kopture et al. 1996). Heidari (2012) reported that germination vigour indices such as seedling length were not influenced by defoliation even though seed vigour, root and seedling length responded positively to defoliation. However, in order to accomplish convenience of seed selection, cob health and discriminative threshing based on seed position on the cob (seed size) have been employed (Louette and Smale 2000). These strategies reportedly enhance seed quality (Msuya and Stefano 2010) and increase yield with ~43.2 percent (Louette and Smale 2000). In terms of seed quality, it was reported by Msuya and Stefano (2010) that large proximal seeds germinated faster and produced vigorous seedlings compared to small distal seeds. Similarly, Graven and Carter (1990) and Pommel et al. (1995) reported larger seeds to have early emergence and seedling development than smaller seeds. Therefore, distal seeds are traditionally discriminated, also due to high vulnerability to fungi and pest infestations as the husk may uncover the seeds and expose them (Msuya and Stefano 2010).

Although seed selection may enhance seed quality, this seed property in most crops is vulnerable to defoliation from biotic and abiotic factors. However, the response may be subject to defoliation level, plant growth stage (Hicks et al. 1977; Vasilas and Seif 1986), genotype and environmental conditions (Vasilas and Seif 1986). Vasilas and Seif (1986) established that the detrimental effects of defoliation are exacerbated at reproductive stages of maize such as grain-filling.

There is a large body of evidence about the importance of soil fertility, drought, poor management, weeds, diseases, and pests as factors affecting maize crop yield (Sakala and Kabambe 2004), whereas, the effects of hail damage have not been widely reported. In addition, the objective of crop improvement usually prioritizes crop yield quality rather than seed quality. While the agronomic aspects of hail damage have been studied in other parts of the world, especially in the developed world, no studies have been published to show what effect hail damage has on seed quality especially with respect to maize crop in the developing world. There is, therefore, an apparent research gap that may be explained by combining agronomy and indigenous knowledge in seed science. In this study, the knowledge gap is looked into in the context of hail damage, an environmental factor linked to climate change.

METHODOLOGY

Seed Quality Survey

Seed quality survey was conducted from the subsistence farmers of three districts in KwaZulu Natal (KZN). The target population from the study was sixty maize subsistence farmers of KZN where twenty was from each of the following districts: Esikhaleni, Swayimane and Umbumbulu. The representatives of each district were randomly selected to meet the requirements of the study. The results of the survey were subjected to statistical analysis using SPSS software. The survey does not include subsistence farmers from the cities but those from rural areas. Therefore it represents underdeveloped and developing areas. The survey focused on how farmers choose their seeds, the reasons for such practices and if they have knowledge about the seed quality as well as its relevance.

Subsequent Seed Quality Response to Simulated Hail Damage

The effect of simulated hail damage on seed quality was assessed on three popular maize cultivars [SC701, MacMedium Pearl (MMP) and Zama Star (ZS)] in South Africa. Two significantly different bioclimatic areas of KwaZulu-Natal (Baynesfield and Swayimane) were used to ensure genotype x environment interaction. A randomised complete block design replicated three times was used for seed production. Since climate change has led to unpredictability of seasons, it is important to determine at which stages of development is maize vulnerable or resistant to hail damage. Therefore, three stages of simulated hail damage were Control (no damage), V7 (damage at the 7th leaf stage) and VT (damage at tasselling stage) in three plant population densities [High (65000 plants/ha), Moderate (46000 plants/ha) and Low (28000 plants/ha)]. Grain was harvested at maturity and seed quality tests were carried out after dividing the maize cob into two halves (Proximal and Distal) for seed position factor. In addition to thousand grain mass, laboratory seed quality (viability and vigour) assessments were conducted at the University of KwaZulu–Natal's Seed Technology Lab according to ISTA (2012). A completely randomised design replicated four times was used for viability (response to tetrazolium chloride) and standard germination tests, to allow for determination of vigour indices [germination vigour index, mean germination time, seedling length (shoot, root and total) and seedling mass (fresh and dry) as well as root to shoot ratio]. Seed quality mean germination time (MGT) and germination vigour index (GVI) determination was measured as explained in equations 1 (Ellis and Roberts 1981) and 2 (Maguire 1962), respectively:

$$MGT=\frac{\Sigma\, D\, n}{\Sigma n} \quad \text{Equation 1}$$

where: D is the number of days from the beginning of germination, and

n is the number of seeds that have germinated on day D

$$GVI = G1/N1 + G2/N2 + \ldots + Gn/Nn \quad \text{Equation 2}$$

where: GVI = germination velocity index,

$G_1, G_2 \ldots G_n$ = number of germinated seeds in first, second… last count, and

$N_1, N_2 \ldots N_n$ = number of sowing days at the first, second… last count.

RESULTS AND DISCUSSION

Seed Quality Survey

The study indicates that farmers had knowledge and preference for certain maize cultivars, seeds and their quality aspects. For instance, Table 1 shows knowledge about seed quality and its importance according to respondent subsistence farmers from KZN districts (Esikhaleni, Swayimane and Umbumbulu).

Farmers had a preference for seeds harvested from previous crops and larger seeds. Farmers knew the importance of kernel position and its effect on seed quality. Farmers prefer seed from the middle part of the cob (Table 1). This finding concurs with Oakley and Momsen (2007)

Table 1: Knowledge about seed quality and its importance according to subsistence farmers from KZN districts (Esikhaleni, Swayimane and Umbumbulu)

Seed quality practices		*Esikhaleni*	*Swayimane*	*Umbumbulu*
			In percent	
Know the maize cultivars they plant		95	90	90
Purchase seeds (from neighbors)		0	28.33 (0)	0
Use seeds saved from previous harvest		18.33	1.67	33.33
Use donated seeds from local neighbors		0	1.67	0
Relevance of seed size in plant production		100	100	100
Preferred seeds size:	(Small)	0	5	10
	(Medium)	15	55	5
	(Large)	85	40	85
The relevance of kernel position		100	100	100
The effects of kernel position on seed quality		100	100	95
Position from which seeds are selected:				
	Distal	1.67	1.67	10
	Middle	31.67	15	18.33
	Proximal	0	6.67	5
	Whole cob	0	10	0

and Fernandez (2007), who reported that indigenous seed practices and systems are vital in developing sustainable agriculture.

Table 2 presents the advantages and disadvantages of the farmers' desired seed sizes. The advantages of selecting particular seeds are related to seed quality (Table 2). The advantageous attributes included; good growth, high yields, big cobs, high (sowing) seed number, good taste and dwarf plants. The disadvantageous attributes include; significantly large cobs, significant number of seeds required for sowing, large area required for sowing, large number of grains on the cob and small cobs.

In a previous study respondents outlined the principal motive for seed selection being ensuring high seed quality and germination (Louette and Smale 2000). These seed properties are of high importance especially since lack of improved seeds is among the hindrances against adapting to climate change (Ishaya and Abaje 2008). Therefore, these finding indicates farmers' knowledge of seed quality for agronomic practices which may in turn facilitate adaptability to climate change.

Subsequent Seed Quality Response to Simulated Hail Damage

The different seed quality aspects determined in this study are presented in Table 3. There were significant effects (P<0.05) of hail damage, cultivar, position on the cob and site on one thousand grain mass (1000 GM). Siahkouhian (2012) also reported that cultivars had an influence on 1000 GM. One thousand grain mass was shown to decrease from control (no hail damage) to hail damage at V7 and VT, respectively. For cultivars, 1000 GM was highest for SC701, MMP and ZS, respectively. With respect to BRGs, 1000 GM was higher for seed produced at Baynesfield than Swayimane with proximal seeds being heavier than distal seeds. The interaction of plant density, hail damage, and cultivar was significant (P= 0.007) for 1000 GM (Table 3). The SC701 variety responded positively to high plant density and hail damaged imposed at growth stage V7.

The individual experimental factors (Site, Position, Hail, Density and Cultivar) had no significant effect on seed viability based on the tetrazolium test. However, their interactions were significant (P < 0.05) including the five way interaction (Site*Position*Hail*Density* Cultivar).

This suggested that seed viability is the outcome of interactive processes rather than individual factors. The results of this study (Table 3) showed that the most viable cultivar was SC701 while ZS was the least viable. Moreover, plant population density that yielded highly viable seeds was the highest one and least from lowest plant density. However, hail damage at VT resulted in viable seeds than no hail damage control.

There was a highly significant effect (P< 0.001) of position on the cob, plant density and site on maize germination over seven days. Similar to Pommel et al. (1995), small distal seeds had low rate of emergence than large proximal seeds. This poor emergence may be attributed to higher chances of pericarp damage on the distal small seeds in addition to size. The pericarp will be mostly damaged when the cob is not well covered by the husk which is highly likely in the cob tip.

Table 2: The advantages and disadvantages of the farmers' desired seed sizes

	Attributes	*Esikhaleni*	*Swayimane*	*Umbumbulu*
			In percent	
Advantages	Good growth	18.33	1.67	3.33
	High yields	5	6.67	0
	Big cobs	10	21.67	0
	High (sowing) seed number	0	0	26.67
	Good taste	0	3.33	0
	Dwarf plants	0	0	3.33
Disadvantages	None	31.67	21.67	3.33
	Produces significantly large cobs	1.67	6.67	0
	Significant number of seeds required for sowing	0	0	1.67
	Large area required for sowing	0	0	1.67
	Large number of grains on the cob	0	5	0
	Small cobs	0	0	26.67

Table 3: The interactive effect of hail damage with cultivar and plant density on seed quality and seedling vigour indices. Explanation of variables is given in the methodology section

Hail damage	*Cultivar*	*Density*	*1000 GM*	*TZ-test*	*GVI*	*Length*	*Shoot length*	*Dry mass*
CONTROL	*SC701*	High	450.94	91.25	53.54	171.81	86.48	0.314
		Moderate	456.32	96.25	45.48	202.19	99.52	0.268
		Low	438.2	89.48	46.23	213.25	101.83	0.258
	MMP	High	458.48	88.12	47.44	216.77	105.72	0.283
		Moderate	402.36	89.58	47.94	209.6	107.08	0.271
		Low	412.95	85.62	40.66	213.25	105.73	0.404
	ZS	High	391.63	87.71	50.29	203.38	102.9	0.253
		Moderate	409.85	82.08	48.82	235.77	109.85	0.193
		Low	468.43	89.58	44.84	232.06	98.12	0.34
V7	*SC701*	High	479.31	92.5	46.44	211.77	102.68	0.317
		Moderate	394.97	82.4	57.87	225.99	118.38	0.263
		Low	476.84	87.92	49.97	179.48	91.25	0.339
	MMP	High	403.48	84.38	45.61	160.5	86.75	0.289
		Moderate	445.42	85.42	49.13	205.54	99.15	0.305
		Low	389.63	83.54	46.49	186.48	91.87	0.244
	ZS	High	393.57	84.58	42.23	201.12	113.04	0.277
		Moderate	346.72	81.46	40.8	215.1	94.75	0.218
		Low	435.84	86.88	42.8	206.29	96.75	0.314
VT	*SC701*	High	404.46	85.42	44.93	209.4	104.4	0.281
		Moderate	450.35	86.67	54.94	175.15	93.85	0.291
		Low	419.59	91.04	39.11	199.44	105.5	0.309
	MMP	High	424.57	92.29	46.27	207.9	99.71	0.269
		Moderate	408.38	91.25	49.47	215.47	117.04	0.259
		Low	401.53	91.88	46.23	195.58	105.37	0.34
	ZS	High	387.08	89.38	49.2	171.47	88.29	0.153
		Moderate	379.49	88.75	54.38	185.82	93.17	0.285
		Low	387.73	85.62	45.07	202.5	107.87	0.279
F. Prob			0.007	0.049	0.030	0.040	0.002	0.010
LSD			57.12	7.24	6.50	34.195	15.81	0.07
CV			16.9	10.2	17.1	21.0	19.4	37.9

These experimental factors (position on the cob, site and density) also showed a significant interaction ($P<0.05$) on seed germination of maize (Fig. 1).

For Baynesfield, moderate plant density and proximal seeds had the highest germination rate. Heidari (2013) argued that seed germination capacity may be affected by the environment of the maternal plant. The environmental factors that plants in this study were exposed to are plant defoliation due to simulated hail damage as well as plant density-induced microclimate. Although the cultivars did not have any significant effect, there were significant differences ($P<0.05$) over the period of seven days in terms of germination percentage (Fig. 2).

Germination scores on day one showed similarities between MMP and ZS. However, on day two the similarities were among cultivar SC701 and MMP. Moreover, on day four all the cultivars performed at the same level of germination. Finally, from day five, MMP started to outperform the other cultivars in terms of germination. Even though the lowest in the beginning of germination period, MMP had the highest germination percentage on the final day of germination. However, overall cultivar SC701 had the highest rate over the period of seven days followed by MMP and then ZS.

In this study, there was no significant influence ($P>0.05$) of hail damage on germination. However, in another study, the only effect ($P<0.05$) of defoliation was decreased seed size which enhanced reduced germination (Vasilas and Seif 1986). Pommel et al. (1995) further alluded that seedlings resulting from larger seeds were larger than smaller seeds at the same stage. This was attributed to the reduction in sucrose supply to the developing seed which is vital for seedling development (Singh and Nair 1975).

Similarly, in this study the distal seeds from both sites showed germination at lower range than the proximal seeds which were bigger compared to distal seeds (Fig. 3).

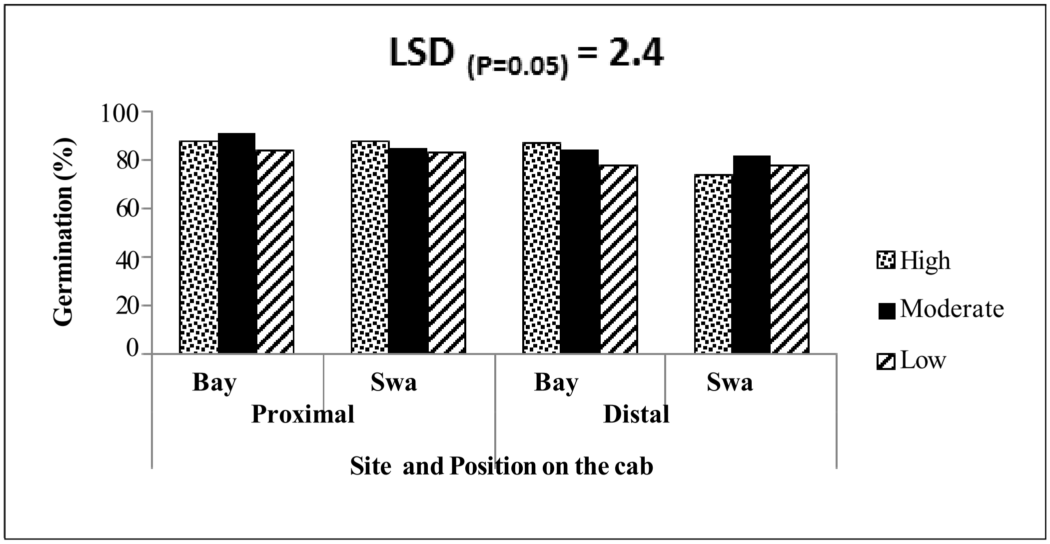

Fig. 1. Germination response to the interaction of plant density (High, Moderate and Low), site and seed position (Proximal and Distal) on the cob (Bay = Baynesfield; Swa = Swayimane)

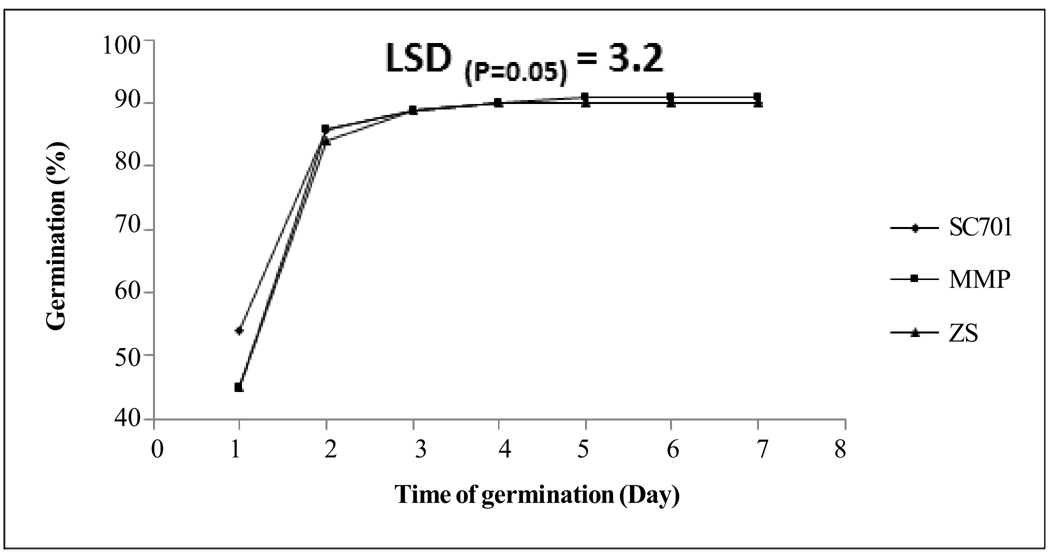

Fig. 2. The rate of germination over the period of seven days in different cultivars (SC701, MMP and ZS)

According to Lopez-Castaneda et al. (1996), the embryo that the larger seed commonly contains is larger and consequently increases chances of germination. Seed size and sucrose for the developing seedling may have led to this trend which concurs with Vasilas and Seif (1986). On the other hand, even though there is a direct relationship between seed reserves which are available for germination and seedling growth, these may be independent of seed size (Pommel 1990). Another factor that contributes to more reserves being converted into seeds is high leaf area which intercepts high solar radiation especially in the absence of any defoliation (Gosse et al. 1986).

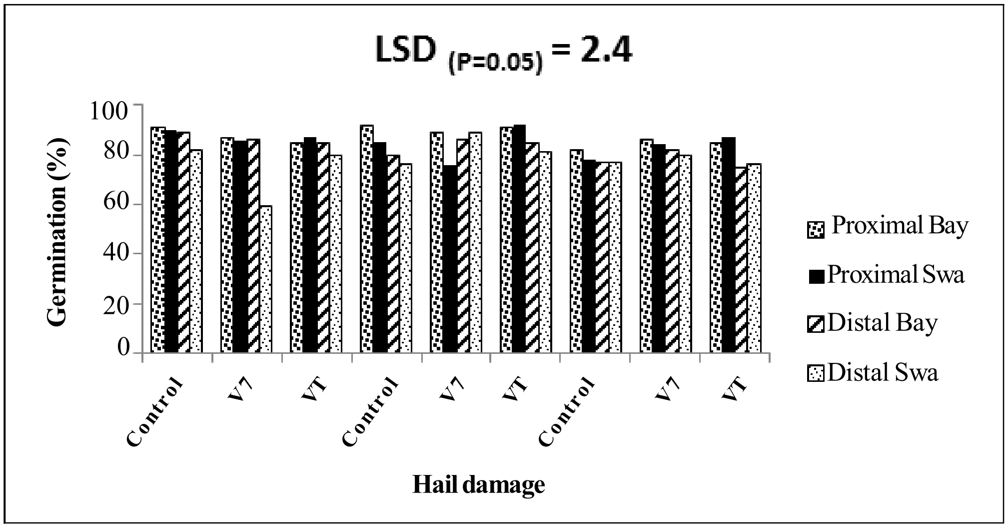

Fig. 3. The effect of the interaction between hail damage (Control, V7 and VT), seed position on the cob (Proximal and Distal) and site (Bay = Baynsfield; Sway = Swayimani)

It was confirmed by Msuya and Stefano (2010) that high quality seeds were found from the proximal than distal seed position which results in low yield. The authors further alluded that the distal seeds on maize cob are highly exposed to fungi and insect pest infestations while on the mother plant as they may be uncovered by the husk. Therefore, the physical aspect of seed quality may be compromised by not only disease infestations but also birds and insects may feed on the crop hence causing damage and inferior seed quality. Moreover, Msuya and Stefano (2010) also reported larger proximal seeds to significantly result in vigorous seedlings.

In addition to the significant factor interactions with respect to germination vigour index (GVI), plant density and position on the cob were significantly different ($P<0.05$). Moderate plant density had the highest vigour index followed by high and low, respectively.

It is evident that when cultivar SC701 at moderate population density was hail damaged at V7 it had the highest GVI. However, when the same cultivar is at low population density and hail damaged at VT it shows the lowest GVI. Therefore, it can be concluded that V7 and moderate plant density are superior compared to VT and low plant density.

Cultivar and plant density significantly differed for mean germination time (MGT). Moreover, there was a significant interaction ($P<0.05$) of seed position on the cob, plant density and hail damage simulation on mean germination time (Fig. 4). Proximal seeds from plant moderate plant density when damaged at VT took the shortest time to germinate compared to same hail damage from distal position under low plant density which took longest to germinate. These results also agree with those of Msuya and Stefano (2010) who showed significant differences between distal and proximal seeds with respect to MGT. This means that since the small distal seeds are associated with less vigour they will in turn result in poor seedlings, thus should be discriminated during seed selection by the farmers (Msuya and Stefano 2010).

There were significant differences among plant densities and sites on seedling dry mass. The major significant interaction with respect to seedling dry mass was the five way interaction of all the experimental factors on seedling dry mass (Table 3). There is an advantage of low plant density in cultivar MMP when there is no hail damage in terms of seedling dry mass. The opposing results were expressed by ZS at high plant density when there is hail damage at VT

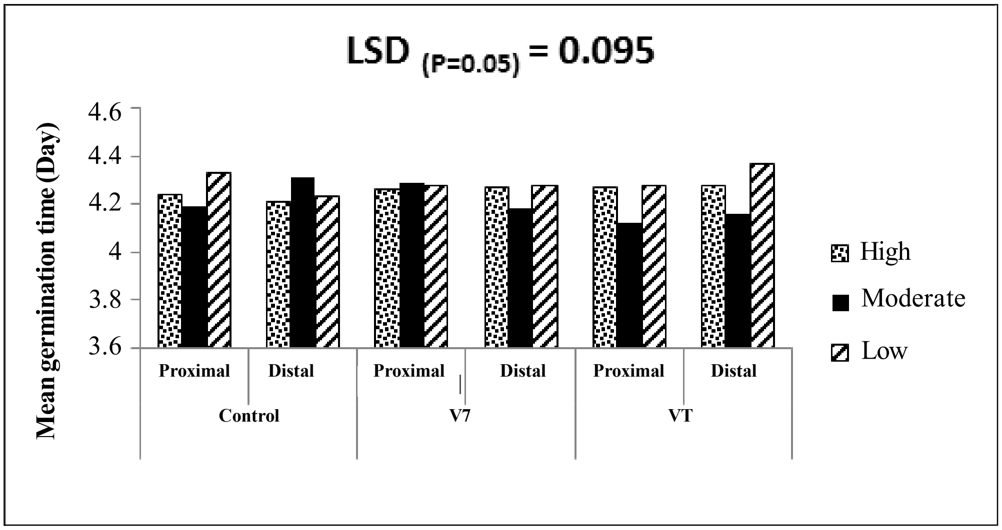

Fig. 4. Mean germination time in response to plant density (High, Moderate and Low), seed position (Proximal and Distal) on the cob and hail damage (Control, V7 and VT)

stage. In terms of seed position on the cob, seedling dry matter content significantly increased from proximal compared to distal seeds (Table 3). Louette and Smale (2000) also reported that proximal seeds have significantly vigorous seedlings than distal seeds.

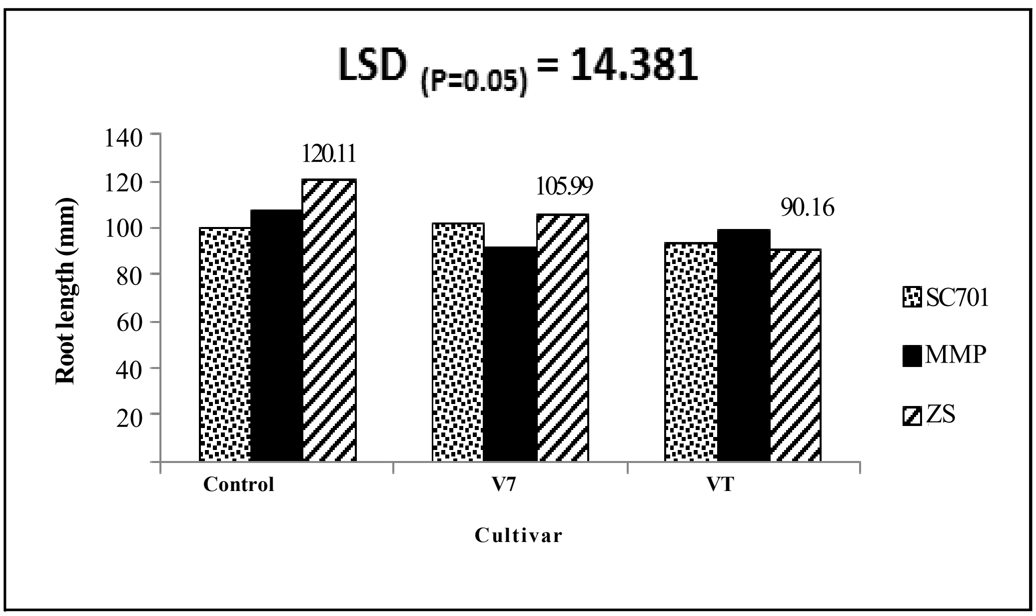

Fig. 5. Root lengths of three maize cultivars (SC701, MMP and ZS) in response to simulated hail damage (Control, V7 and VT)

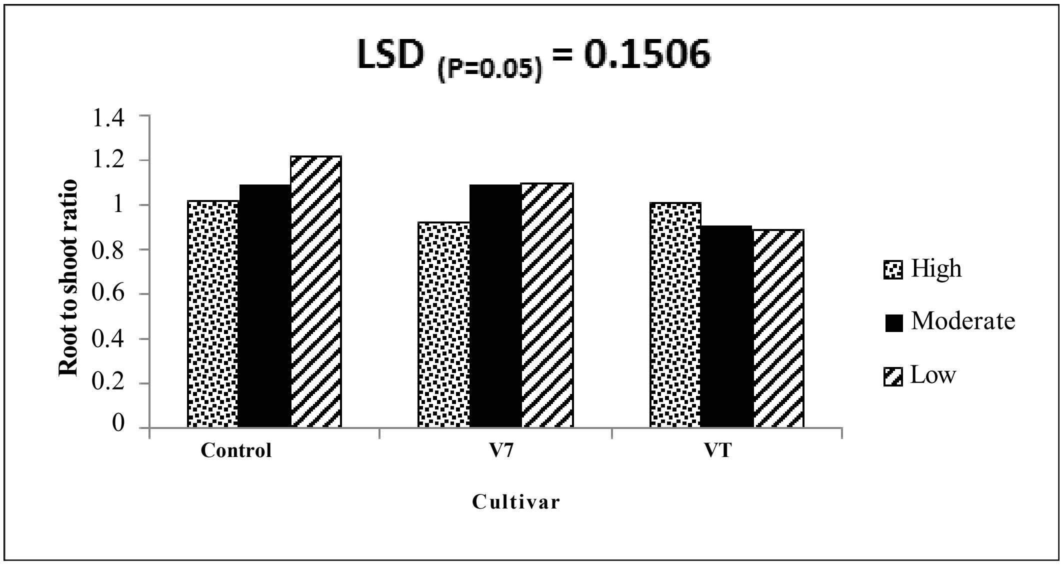

Fig. 6. The interactive effect of plant density (High, Moderate, and Low) and hail damage (Control, V7 and VT) on root to shoot ratio

Plant density and hail had a significant effect ($P<0.05$) on seedling length (Table 3). Moreover, all five factors differently interacted to significantly affect ($P<0.05$) seedling length. Hail damage, cultivar and density significantly interacted ($P<0.05$) to influence seedling length (Table 3). Cultivar ZS responded positively to no hail damage (control) when grown under moderate plant density rather than MMP at V7 when grown under high density with respect to seedling length.

Hail damage had a significant influence ($P<0.05$) on root length. There was also a significant interaction ($P<0.05$) between cultivar and hail damage (Fig. 5). Cultivar SC701 performed better when it was damaged at V7 while MMP and ZS could not adapt to any hail damage as had longest roots as a consequence of no hail damage.

There was a significant interaction ($P<0.05$) between hail damage, plant density and cultivar which significantly affected shoot length ($P<0.05$). Cultivar SC701, under moderate plant density, when damage was simulated at V7, resulted in seedlings with longest shoot length; however, the same cultivar under high plant density with no hail damage had the shortest shoots (Table 3).

Hail damage had a highly significant effect ($P<0.001$) on root to shoot ratio (R:S) of maize seedlings (Fig. 6). There was a significant interaction between hail damage and plant density ($P<0.05$). Seedlings performed better in terms of R:S ratio when they were not damaged. Hail damage at tasselling had the most negative effect on R:S (Fig. 6). This means that hail damage causes seedlings to have a poor root system for initial seedling establishment.

CONCLUSION

This study indicated that subsistence farmers have knowledge about maize seed quality aspects. This can be related to local indigenous knowledge derived from their experience with respect to growing the crop as a staple in their culture. The farmers identified advantages associated with position of the seed on the cob, which matched the scientific findings of the laboratory study on seed quality following an agronomic field trial on the effect of environmental factors of hail damage and plant density. Although not all the seed performance aspects determined in this study were not directly linked to the farmer responses, the ones that were linked (position on the cob and seed size) showed clear evidence of comparability indigenous knowledge and science. Thus, it can be argued that indigenous knowledge is science.

RECOMMENDATIONS

The findings of this study can be used to relate traditional systems of maize production in terms of selecting strategies to mitigate hail damage effects of climate change. Further research can still be done to select for and come up with hail resistant cultivars of maize and other important food security and industrial crops and formulate climate change adaptation strategies using both IK and scientific research. This is important, especially since there is a need for sustainable solutions to climate change.

REFERENCES

Abaje IB, Giwa PN 2007. Urban Flooding and Environmental Safety: A Case Study of Kafanchan Town in Kaduna State. *A Paper Presented at the Golden Jubilee (50th Anniversary) and 49th Annual Conference of the Association of Nigerian Geographers (ANG),* Scheduled for 15-19 October, 2007 at the Department of Geography, University of Abuja, Gwagwalada-Abuja.

Achiando AG, Birech R, Ochola W 2010. Identifying Indigenous Knowledge and Effective Communication Systems for Adaptation to Climate Change by Smallholder Farmers of Kilifi District, Kenya. *Second RUFORUM Biennial Meeting,* 20-24 September, Entebbe, Uganda, pp. 1769-1773.

Bishaw Z, Struik PC, Van Gastel AJG 2012. Farmers' seed sources and seed quality: Physical and physiological quality. *J Crop Improv,* 26: 655-692.

Bore JK, Cheserek BC, Ngetich WK, Yegon SK 2011. An analysis of the incidences of hail damage in tea areas of Kenya. *Tea,* 32: 15-20.

Botzen WJW, Bouwer LM, van den Bergh JCJM 2010. Climate change and hailstorm damage: Empirical evidence and implications for agriculture and insurance. *Resou and Energy Econ,* 32: 341-362.

Cline WR 2007. *Global Warming and Agriculture: Impact Estimates by Country*. Washington DC: Centre for Global Development and Peterson Institute for International Economics.

Dewi PP 2009. Climate change impacts on tropical agriculture and the potential of organic agriculture to overcome these impacts. *As J Food Ag-Ind,* Special Issue, S10-S17.

Egeru A 2012. Role of indigenous knowledge in climate change adaptation: A case study of the Teso Sub-Region, Eastern Uganda. *Indian Journal of Traditional Knowledge,* 11: 217-224.

Elia EF, Mutula S, Stilwell C 2014. Indigenous knowledge use in seasonal weather forecasting in Tanzania: The case of semi-arid central Tanzania. *SA Jnl Libs & Info Sci,* 80: 18-27.

Fernandez PG 1994. Indigenous seed practices for sustainable agriculture. *Indigenous Knowledge and Development Monitor,* 21: 9-12.

Gelmond H, Luria I, Woodstock LW, Perl M 1978. The effect of accelerated ageing of sorghum seeds on seedling vigour. *J Exp Botany,* 29: 489-495.

Gosse G, Varletgrancher C, Bonhomme R, Chartier M, Allirand JM, Lemaire G 1986. Maximum dry-matter production and solar-radiation intercepted by a canopy. *Agronomie,* 6: 47-56.

Gyampoh BA, Amisah S, Idinoba M, Nkem J 2009. Using traditional knowledge to cope with climate change in rural Ghana. *Unasylva,* 60: 70-74.

Heidari H 2013. Yield, yield components and seed germination of maize (*Zea mays* L.) at different defoliation and tassel removal treatments. *Philipp Agric Scientist,* 96: 42-47.

Hicks DR, Nelson WW, Ford JH 1977. Defoliation effects on corn hybrids adapted to the northern corn belt. *Agron J,* 69: 387-390.

Ishaya S, Abaje IB 2008. Indigenous people's perception on climate change and adaptation strategies in Jema'a local government area of Kaduna State, Nigeria. *J Geogr Reg Plann,* 1: 138-143.

Joranson K 2008. Indigenous knowledge and the knowledge commons. *Int Inf Libr Rev,* 40: 64-72.

Kerr DS 2009. *Seed Quality and the Use of Organic Treatments to Improve Crop Performance*. MSc Dissertation. Halifax, Nova Scotia: Dalhousie University, P. 24.

Kopture S, Smith KL, Lawton JH 1996. Effect of artificial defoliation on reproductive allocation in the common vetch *Vicia sativa* (Fabaceae; *papilionoideae*). *Amer J of Bot,* 83: 886-889.

Lemons H 1942. Hail in American agriculture. *Econ Geogr,* 18: 363-378.

Li C, Tang Y, Luo H, Di, B, Zhang L 2013. Local farmers' perceptions of climate change and local adaptive strategies: A case study from the middle Yarlung Zangbo River Valley, Tibet, China. *Environ Manage,* 52: 894-906.

Lopez-Castaneda C, Richards RA, Farquhar GD, Williamson RE 1996. Seed and seedling characteristics contributing to variation in early vigor among temperate cereals. *Crop Sci,* 36: 1257-1266.

Louette D, Smale M 2000. Farmers' seed selection practices and traditional maize varieties in Cuzalapa, Mexico. *Euphytica,* 113: 25-41.

Milosevic M, Vujakovic M, Karagic D 2010. Vigour tests as indicators of seed viability. *Genetika,* 42: 103-118.

Mirza MMQ 2003. Climate change and extreme weather events: Can developing countries adapt? *Clim Policy,* 3: 233-248.

Msuya DG, Stefano J 2010. Responses of maize (*Zea mays*) seed germination capacity and vigour to seed selection based on size of cob and selective threshing. *World J Agri Sci,* 6: 683-688.

Ngaira JKW 2007. Impact of climate change on agriculture in Africa by 2030. *Sci Res Essays,* 2: 238-243.

Nkomwa EC, Joshua MK, Ngongondo C, Monjerezi M, Chipungu F 2014. Assessing indigenous knowledge systems and climate change adaptation strategies in agriculture: A case study of Chagaka Village, Chikhwawa, Southern Malawi. *Phys Chem Earth,* 67-69: 164-172.

Oakley E, Momsen JH 2007. Women and seed management: A study of two villages in Bangladesh. *Singap J Trop,* 28: 90-106.

Omara P 2013. *Effect of Seed Distribution and Population on Maize (Zea Mays L.) Grain Yield*. MSc Dissertation. Stillwater, Oklahoma: Oklahoma State University.

Pommel B, Goytino B, Bonhomme R 1995. Effects of seed size, seed position on the parent cob and parental cob size on the leaf area of maize under field conditions. *Eur J Agron,* 4: 363-369.

Rajasekaran B 1993. *A Framework for Incorporating Indigenous Knowledge Systems into Agricultural Research and Extension Organizations for Sustainable Agricultural Development in India*. PhD Dissertation. Ames, Iowa: Iowa State University.

Rajjou L, Duval M, Gallardo K, Catusse J, Bally J, Job C, Job D 2012. Seed germination and vigor. *Annu Rev Plant Biol,* 63: 507-533.

Sakala WD, Kabambe VH 2004. *Maize Agronomy Research Report 2000-2003*. Lilongwe, Malawi: Chitedze Research Station, Ministry of Agriculture Irrigation and Food Security, P. VIII.

Siahkouhian S, Shakiba MR, Salmasi MZ, Ghassemi-Golezani K, Toorchi M 2012. Defoliation Effects on Yield Components and Grain Quality of Three Corn Cultivars. *International Conference on Environment, Agriculture and Food Sciences (ICEAFS' 2012)*, 11-12 August, Phuket, Thailand.

Sillitoe P 1998. The development of indigenous knowledge: A new applied anthropology. *Curr Anthropol,* 39: 223-252.

Singh RP, KKP Nair 1975. Defoliation studies in hybrid maize II. Dry matter accumulation, leaf area index, silking, and yield components. *J Agric Sci Camb,* 85: 247-254.

Sisu M, Mircov VD, Nita S 2011. Hail - phenomena of risk for agriculture. *Research J Agric Sci,* 43: 490-496.

Tenaillon MI, Charcosset A 2011. A European perspective on maize history. *CR Biologies,* 334: 221-228.

Tollenaar M, Daynard TB 1978. Effect of defoliation on kernel development in maize. *Can J Plant Sci,* 58: 207-212.

Vasilas BL, Seif RD 1985. Defoliation effects on two corn inbreds and their single cross hybrid. *Agron J,* 77: 816-820.

Vasilas BL, Seif RD 1986. Effect of defoliating corn inbreds on seed quality. *J Seed Technol,* 10: 121-128.

Ventura L, Dona M, Macovei A, Carbonera D, Buttafava A, Mondoni A, Rossi G, Balestrazzi A 2012. Understanding the molecular pathways associated with seed vigor. *Plant Physiol Biochem,* 60: 196-206.

White PJ, Johnson LIA 2003. *Corn: Chemistry and Technology*. 2nd Edition. St. Paul, MN: American Association of Cereal Chemists Inc.

Zhao JL, Zhang DY, Luo JH, Huang SL, Dong YY, Huang WJ 2012. Detection and mapping of hail damage to corn using domestic remotely sensed data in China. *Aust J Crop Sci,* 6: 101-108.