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Effect of Harvesting Stages and Nitrogen on Seed Quality and Yield of Jute Mallow (*Corchorus olitorius L.*)

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Abstract
Production of high quality seeds in African leafy vegetables has not been practiced due to varying reasons including incorrect harvesting stages and fertilizer rates. Jute mallow (*Corchorus olitorius* L.) pods do not ripen simultaneously and fruits left to dry on mother plant long before harvesting, which face seed quality deterioration. Timely seed harvesting ensures maximum seed quality attributes of purity, germination and vigour. The present study aimed to investigate the effects of harvesting stages and nitrogen fertilizer on seed quality and yield of Jute mallow. Seed samples from four Jute mallow morphotypes (GEMS, GLMT, BEMS, and BLMT) were planted. Completely randomized block design was used for analysing the effects of nitrogen fertilizer levels (0, 60 and 120 kg/ha) with three replicates. Five plants were randomly tagged per plot and seed harvested at three maturity stages of green, tan and black. Seed quality test of purity, germination and vigour were done as per ISTA (2004) and means separation done by DMRT at $p \leq 0.05$. Results showed that harvesting stage significantly influenced seed quality attributes, in a way that the maximum purity, germination and seed vigour was detected at tan pod stage and their lowest levels were observed at black pod stage. It can be concluded that best agronomic practices of Jute mallow seed can be attained when they harvested at tan stage together with use of N fertilizer for high seed quality and yield.

Keywords: African leafy vegetables, ripening, pods, harvesting stage

Introduction

Jute mallow (*Corchorus olitorius* L.) is a vegetable produced in dry, semi-arid regions and in humid areas (Faber, et al., 2010). It is considered as a healthy vegetable as it meets major protein-calorific nutritional needs (MOA, 2015) and contains vitamins, minerals, dietary fiber and protein required for health (Nyadanu and Lowor, 2014). *C. olitorius* is susceptible to moisture stress and negatively influenced owing to its shallow rooting depth (KALRO, 2016), thereby its production is limited to rainy season (Abd-Allah, et al., 2010). In Jute mallow farming, plant nutrition is essential especially for nutrients like nitrogen (N), phosphorus (P) and potassium (K) to enhance yield (Aisha, et al., 2013). Fertilizer generally promotes plant growth and subsequent seed quality and yield (Olaniyi, 2000; Jonathan, et al., 2012; Rutto, et al., 2018). Fertilizer studies in South Western Nigeria showed positive responses of *C. olitorius* to nitrogen (Nihort, 1986). Nitrogen fertilizer greatly improves

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micronutrient content (e.g., Fe, P, and Ca) as well as carotene and vitamin C; however, Olaniyi, and Ajibola, (2008) found that, soil application of N, P and K significantly improves plant growth. Other studies on different crops by Ahmadi et al., (2010) on spinach plants; Islam et al., (2011) on radish plant; Hassanzadeh, et al., (2017) on essential oil content, composition and rosmarinic acid in *Rosmarinus officinalis* L. plants showed that response to NPK fertilizer on plant growth and harvest. In other research by Ahmed et al., (2000) showed that high level of nitrogen fertilization increases fresh yield of rocket leaves by 50.0% and 16.4% in the 1st and 2nd cuts.

Worldwide, farmers grow vegetable landraces which differ in plant growth requirements (MOA, 2016). Production of high quality ALVs seeds has not been practiced (Abukutsa-Onyango, 2002). Jute mallow farming indicates that producers re-cycle seed thereby lowering yields (Chweya and Ezyaguirre, 1999; Abukutsa-Onyango, 2007; Kalro, 2016). To increase production of Jute mallow to meet its high demand, mature pods needs to be harvested at correct harvest stage (KALRO, 2015). Improved husbandry practices increases Jute mallow production by over 70% (MOA, 2014). Quality seed is a key element for a successful crop production (Ochuodho, 2005). Seed quality is determined by several internal and external factors that influenced seed development and maturation (Maina et al., 2013).

At green pod harvest stage, seed quality in terms of germination is higher than black pod harvest stage though seeds are not dry enough and can be damage during processing and storage (Keding, 2007). The quality of seed would be enhanced at physiological maturity when the maximum of the seeds sown germinate and produce normal and vigorous seedlings (Hilhorst and Toorop, 1997; Kamotho, 2004). It has been shown that Jute mallow pods do not ripen simultaneously and left to dry long on mother plant before harvesting, which result in seed losses like deterioration due to unfavorable weather, lodging and shattering (Schippers, 2002; Kalro, 2015). These loses could be reduced by hand-picking seed pod at mature stage, followed by seed extraction and drying (K'Opondo, *et al*., 2005). Most farmers collect ALVs seed for planting from volunteer plants; propagate for home use and for sale in local markets (Simiyu, et al., 2003; Aura, 2014).

Jute mallow production requires high quality seed for its sustainability and profitability (Olaniyi, and Ajibola, 2008). However seed production system of many indigenous vegetables worldwide is largely informal (Ndinya, 2005). Farmers often produce and store their own seed and distribute them among themselves without knowing seed quality status in terms of purity, germination or vigour (Ngoze and Okoko, 2005). This is due to many factors including inadequate knowledge of seed quality aspects (Okongo, 2005). Science dictates that a high quality seed should be viable and germinate easily to develop into a plant under favorable conditions (Gómez-Campo, 2007). Kamotho et al. (2014) and Rutto et al. (2018) indicated that seed viability has a direct relation and is actually represented by the germination percentage. The viability of seed is very critical for better production of crops derived from the seed (Kamotho et al., 2007) and the methods used such as; germination test, imbibition test, tetrazolium test and etc. but germination test remains the most reliable and effective method for assessing viability and vigour (Gold et al., 2008).

Biodiversity International reports over 20 leafy vegetable species presented and are specific to Africa though with vivid data (Hodder, 2004). This gap is also reported by Mirghani and Mohammed (1997). Okeno et al. (2003) showed that in contrast to cash crops, little attention has been paid to production of African leafy vegetables and so there is a dearth of data on their production levels, which this research is partially addressing. The availability of reliable information on the production of African leafy vegetables is crucial for any planned attempts to integrate them into global fruit and vegetables production initiative for improved health (Aphane et al., 2002).

Currently there is a knowledge gap on indigenous vegetables (including Jute mallow) as little information is available on seed quality (de Castro et al., 2014). Such recommendation draws attention to existing gap in knowledge and information on production (fertilization, harvesting and storage) of African leafy vegetables. Hypothetically there is dire need for research in stated areas to close this knowledge and information gap so as to increase global attention and get it turned towards mobilizing local biodiversity for food security and health worldwide (Maunder and Meaker, 2007). Hypothesis here is that there would be difference in response of various harvesting stages and fertilizer on yield and seed quality of Jute mallow in terms of analytical purity, germination and seed vigour.

To increase Jute mallow production to meet current high demand of these vegetables (MOA, 2015), there is a need to do investigations on various aspects of production to come up with best agronomic practices that enhances seed quality and yield thereby enabling farmers to maximize profit. Currently Jute mallow farmers plant seeds that have been produced without adequate agronomic practices like fertilizer use, spraying and right harvesting stage as well as correct processing methods (Akamine et al., 2007). Such seeds may express poor germination, vigour and storability thereby leading to low yields, necessitating study to find out effect of harvesting stages and N fertilizer on seed quality and yield of Jute mallow in terms of quality aspects of analytical purity, germination and seed vigor.

Materials and methods

Study sites, Field experimental management and data collection

Jute mallow morphotypes (GEMS, GLMT, BEMS, BLMT) that were used in this experiment were planted at two sites of the University of Eldoret farm (site 1) situated at longitude 0^{o}30’’N and latitude 35’15’’E and altitude of 2140 m above sea level, in Uasin Gishu county, Kenya and KALRO - Kitale farm (site 2) situated at latitude of 1^{o}02’N and 35^{o}E longitude and altitude of 1901 m.a.s.l in Trans Nzoia county, Kenya over one season between May - November. Seeds were drilled after nitrate fertilizer (Calcium nitrate) applied at rate of 0, 60 and 120 kg/ha (Masinde et al., 2010) at experimental plots. Weeding was carried out in all plots in sites simultaneously. Seedlings were thinned two weeks later to spacing of 30 cm x 30 cm (Abukutsa-Onyango, 2007). Data collection was done on five plants randomly sampled (Gomez and Gomez, 1984) in each plot, tagged and seed harvested at three harvest stages of Green, Tan, and Black pod stage. Seeds were then taken to seed laboratory for seed quality tests of analytical purity, germination and seed vigor as per ISTA protocol (2004).

Seed quality test

Analytical purity test

From harvested seed for each stage, a working samples for 15 g was gotten and meticulously examined and separated into three purity portions of pure seed, other seeds in sample e.g., grass seeds, other crop seeds and inert matters (dust, Soil, and etc.). Weights of each portion were noted and their percentages worked out from their initial weight of working sample (15 g) and results analyzed as per ISTA (2004) and reported.

Germination test

At seed lab, four replicates of 100 seeds were obtained randomly from pure seed sample and placed on moistened filter paper inside a Petri dish, ensuring seeds were sufficiently spaced. They were then taken to growth chamber and germination scored daily for 5 days. Thereafter germination was separated into normal seedlings, abnormal seedlings and dead seeds and data analyzed as per ISTA (2004) and results reported.

Electrical conductivity (Seed vigor test)

In electrical conductivity (E.C) test, 250 mL of distilled water was put in 24 well labeled containers (plastic) and covered with aluminum foil to control dust. Two containers of distilled water of 250 mL each were also set as control and covered with aluminum foil. The containers were then put on bench for 24 h at room temperature (20-23 ^oC) and 100 Jute seeds added to each container. After 24 h, contents of containers were gently swirled for 10-15 s and conductivity (µS cm^{-1} g^{-1}) was measured. The data was then analyzed as per ISTA (2004) and results reported.

Data Analysis

The data on seed quality was analyzed as per ISTA (2004) to ascertain harvesting stage and fertilizer level that gives best seed quality attributes and yield while means were separated by DMRT at $p \leq 0.05$.

Results

Effect of harvesting stage and N fertilizer on analytical purity of green pod harvested seed

Seed purity results of green pod stage from site 1 and 2 (Table 1) shows all Morphotype seeds were over 99% purity indicating seeds were of high quality, thereby meeting ISTA (2004) quality status of above 98% purity. Fertilizer rate of 120 kg/ha had higher seed purity (99.9%) by BLMT Morphotype at both site 1 and 2 compared to rate of 60 kg/ha having 99.8% by same BLMT Morphotype at site 2 and control (no fertilizer) with 99.7% by same BLMT Morphotype. The lowest purity belonged to the control (no fertilizer) having 99.4% by GEMS Morphotype at site 1.

Effect of harvesting stage and N fertilizer on analytical purity of tan pod harvested seed

Seed purity results from Tan pod seed stage of Jute Mallow (Table 2) shows all morphotypes seeds were over 99% purity indicating seeds were of high quality, thereby meeting ISTA (2004) seed quality status of above 98% purity. Highest seed purity being at 120kg/ha fertilizer rate of 99.9% by all morphotypes except BLMT (99.8%) from site 1 and BEMS (99.8%) from site 2. Lowest purity at tan stage was at control (no fertilizer) with 99.5% exhibited by GEMS Morphotype at site 1 and GEMS and BEMS morphotypes from site 2.

Table 1. Means of analytical purity (%) of Green pod seed harvesting stage of Jute Mallow (Corchorus olitorius L.)

Fertilizer rates	Site 1 (Eldoret)				Site 2 (Kitale)			
	Morphotypes				Morphotypes			
	GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	99.4a	99.6a	99.5a	99.6a	99.5a	99.5a	99.5a	99.7a
F1	99.7b	99.7b	99.6b	99.7b	99.7b	99.7b	99.7b	99.8b
F2	99.8c	99.8c	99.7c	99.9c	99.8c	99.8c	99.8c	99.9c

Note: (F) denotes fertilizer rates; F0=none, F1=60 kg/ha, F2=120 kg/ha. Numbers having same letters 'a' or 'b' or 'c' in columns shows no significant difference (p<0.05) in means of Morphotype at site.

Table 2. Means of analytical purity (%) of Tan pod seed harvesting stage of Jute Mallow (Corchorus olitorius L.)

Fertilizer rates	Site 1 (Eldoret)				Site 2 (Kitale)			
	Morphotypes				Morphotypes			
	GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	99.5a	99.6a	99.6a	99.6a	99.5a	99.5a	99.6a	99.6a
F1	99.8b	99.7b	99.7b	99.7b	99.7b	99.7b	99.6a	99.7b
F2	99.9c	99.9c	99.9c	99.8c	99.9c	99.8c	99.9c	99.9c

Note: (F) denotes fertilizer rates; F0=none, F1=60 kg/ha, F2=120 kg/ha. Numbers having same letters 'a' or 'b' or 'c' in columns shows no significant difference (p<0.05) in means of Morphotype at site.

Effect of harvesting stage and N fertilizer on analytical purity of black pod harvested seed

Seed purity results from Black pod seed harvesting stage (Table 3) shows all Jute mallow morphotypes seeds were over 99% purity indicating seeds were of high quality in terms of purity, thereby meeting ISTA (2004) quality status of above 98% purity. The highest purity of 99.8% was by GEMS and BEMS morphotypes on fertilizer rate 120kg/ha at site 1 and from all morphotypes at site 2 except GLMT Morphotype (99.7%). The lowest seed purity at black stage was 99.4% by GEMS and BEMS morphotypes from control (no fertilizer) at both sites 1 and 2. At fertilizer rate of 60kg/ha purity was 99.6% across all morphotypes except GEMS (99.7%) at sites 1 and 2.

Effect of harvesting stage and N fertilizer on germination of green pod harvested seed

Results from green pod seeds stage of Jute Mallow (Table 4) shows seed germinations were varied ($p<0.05$) across morphotypes at sites 1 and 2. Most seed germinations were over 75%, indicating seeds were of high quality, thereby meeting ISTA (2004) quality status of above 60% (labeled seed). The highest seed germination was 91% by GLMT Morphotype from site 2 on 120 kg/ha fertilizer and lowest was 75.6% (BLMT Morphotype) from site 1 on control (no fertilizer). Highest purity on 60 kg/ha fertilizer was 84.3% by GLMT and BLMT morphotypes at site 2 and lowest of 81.3% by GEMS Morphotype at site1.

Table 3. Means of analytical purity (%) of Black pod seed harvesting stage of Jute Mallow (Corchorus olitorius L.)

Fertilizer rates	Site 1 (Eldoret)				Site 2 (Kitale)			
	Morphotypes				Morphotypes			
	GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	99.4a	99.4a	99.5a	99.5a	99.4a	99.4a	99.5a	99.5a
F1	99.7b	99.6b	99.6b	99.6b	99.7b	99.6b	99.6b	99.6b
F2	99.8c	99.8c	99.7c	99.7c	99.8c	99.8c	99.7c	99.8c

Note: (F) denotes fertilizer rates; F0=none, F1=60 kg/ha, F2=120 kg/ha. Number having same letters 'a' or 'b' or 'c' in columns shows no significant difference ($p<0.05$) in means of Morphotype at site.

Table 4. Means for germination (%) of green pod seed harvesting stage of Jute Mallow (Corchorus olitorius L.)

Fertilizer rates	Site 1 (Eldoret)				Site 2 (Kitale)			
	Morphotypes				Morphotypes			
	GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	75.7a	76a	75.7a	75.6a	78a	79.6a	77.7a	77.5a
F1	81.3b	81.9b	81.5b	82.2b	83.9b	84.2b	84.3b	84.3b
F2	86.8c	87.5c	88.4c	88.5c	89.4c	90.2c	91c	90.8c

Note: (F) denotes fertilizer rates; F0=none, F1=60 kg/ha, F2=120 kg/ha. Numbers having same letters 'a' or 'b' or 'c' in columns shows no significant difference ($p<0.05$) in means of Morphotype at site.

Radicle emergence results of green pod seeds stage showed significant variation ($p<0.05$) across most morphotypes with average emergence above 75% and highest with 91% and lowest with 75% of radicle emergence. Though radicle seedling emergence was high, sizable number of abnormal seedlings reduced germination percentage to lower levels. There were also a sizable percentage of dead seeds across varieties with lowest percentage of 9% from BEMS and GLMT morphotypes, while highest dead seed was 26% from all morphotypes except BEMS Morphotype with 25%.

Effect of harvesting stage and N fertilizer on germination of tan pod harvested seed

Results from Tan pod seed stage (Table 5) shows seed germinations were varied ($p<0.05$) within treatments and across morphotypes with germination being over 76%, indicating seeds were of high quality thereby meeting ISTA (2004) quality status of above 60% (labeled seed). The highest seed germination was 92.9% from GEMS and BEMS morphotypes at site 2 on 120 kg/ha fertilizer and lowest germination being 76.3% from GLMT Morphotype at site 1 on control treatment (without fertilizer). On 60 kg/ha fertilizer rate highest seed purity was 87.8% by BEMS Morphotype at site 2 and lowest being 84.1% by GLMT Morphotype at site 1.

Radicle emergence results from Tan pod seeds stage showed most varieties had radicle emergence above 75% with highest of 93% by GLMT Morphotype at site 2. Though radicle seedling emergence was high, sizable number of abnormal seedlings reduced germination percentage to lower levels. There were a sizable percentage of dead seeds across morphotypes with lowest percentage at 9% from BEMS and GLMT morphotypes at site 2, while highest dead seed was 24% from all morphotypes except BEMS Morphotype with 22% at site 1.

Effect of harvesting stage and N fertilizer on germination (%) of black pod harvested seed

Results from Black pod stage of Jute mallow (Table 6) shows seed germinations were varied ($p<0.05$) across morphotypes with most seed germinations below 60%, indicating seeds were of poor quality, thereby not meeting ISTA (2004) quality status of labeled seed that have to be above 60%. The highest seed germination was 63.5% by GLMT and BLMT on 120 kg/ha fertilizer rate at site 2 and lowest being 49.3% (BEMS) on control (no fertilizer) at site 1. The highest germinations on 60 kg/ha fertilizer was 58.1% by BLMT Morphotype at site 2 and lowest being 55.1% germination by GEMS Morphotype at site 2.

Table 5. Means for germination (%) of tan pod seed harvesting stage of Jute Mallow (Corchorus olitorius L.)

Fertilizer rates	Site 1 (Eldoret)				Site 2 (Kitale)			
	Morphotypes				Morphotypes			
	GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	78a	79.1a	76.3a	76.8a	79.3a	78.7a	79.8c	77.9a
F1	84.8b	85.1b	84.1b	84.8b	87b	87.8b	86.8b	85.8b
F2	90.5c	91c	91.6c	91c	92.9c	92.9c	93c	92.3c

Note: (F) denotes fertilizer rates; F0=none, F1=60 kg/ha, F2=120 kg/ha. Numbers having same letters ’a’ or ’b’ or ‘c’ in columns shows no significant difference ($p<0.05$) in means of Morphotype at site.

Table 6. Means of germination (%) of black pod seed harvesting stage of Jute Mallow (Corchorus olitorius L.)

Fertilizer rates	Site 1 (Eldoret)				Site 2 (Kitale)			
	Morphotypes				Morphotypes			
	GEMS	BEMS	GLMT	BLMT	GEMS	BEMS	GLMT	BLMT
F0	50.2a	49.3a	50.4a	51.4a	53a	49.5a	50.5a	50.8a
F1	55.1b	55.1b	55.7b	56.5b	57.3b	56.8b	57.7b	58.1b
F2	60.8c	62.3c	62c	62.3c	61.8c	63c	63.5c	63.5c

Note: (F) denotes fertilizer rates; F0=none, F1=60 kg/ha, F2=120 kg/ha. Numbers having same letters ’a’ or ’b’ or ‘c’ in columns shows no significant difference ($p<0.05$) in means of Morphotype at site.

Emergence of radicle from Black pod seed stage shows most morphotypes had their radicle emergence below 60% with highest at 64% by GLMT and BLMT morphotypes on 120 kg/ha fertilizer at site 2 and lowest being 49% by BEMS Morphotype on control (no fertilizer) at site 1. Though radicle emergence was high, sizable number of abnormal seedlings varying from 7-12% reduced germination percentage to lower levels across morphotypes in both sites 1 and 2. There was also high percentage of dead seeds observed across morphotypes and sites with highest and lowest percentage being 49% and 39% by BEMS Morphotype at both sites, respectively.

Seed vigor test (speed of germination) results

Effect of harvesting stage and N fertilizer on seed vigor of green pod harvested seed

The daily speed of germination from green pod harvesting stage of Jute Mallow showed over half (50%) of seeds germinated at the 1st day. By the end of germination period (5th day) the highest germinated seed was 91% from site 2 exhibited by GLMT and BLMT morphotypes on 120 kg/ha fertilizer. At site 1 highest seed vigor was at 89% from all morphotypes except GEMS morphotype, which had 87% on 120 kg/ha fertilizer. On average lowest daily speed of germination was 76% across all morphotypes from site 1 on control treatment (0 kg/ha N fertilizer), while at site 2 lowest seed vigor was 78% by all morphotypes except BEMS, which had 80% seed vigor. The highest seed vigor on 60 kg/ha fertilizer at green pod harvest stage was 84% by all morphotypes at site 2, while the lowest seed vigor was 81% by GEMS Morphotype at site 1 on 0 kg/ha N fertilizer treatment.

Effect of harvesting stage and N fertilizer on seed vigor of tan pod harvested seed

The daily seed germination of Jute Mallow showed over half (70%) of seeds germinated by the end of 1st day. By the end of germination period (5th day) highest seed vigor was 93% from site 2 exhibited by all morphotypes except BLMT Morphotype (92%) on 120 kg/ha fertilizer, while site 1 had highest germination at 91% from all morphotypes on 120 kg/ha fertilizer. On average, lowest daily seed germination was 76% by GEMS Morphotype on control (no fertilizer) from site 1 and site 2. On 60 kg/ha fertilizer treatment, highest seed vigor was 88% by BEMS Morphotype at site 2 and lowest was 84% by GLMT Morphotype at site 1.

Effect of harvesting stage and N fertilizer on seed vigor of black pod harvested seed

Seed vigor of Jute Mallow showed that only 45% of seeds germinated by end of 1st day. By end of germination period (5th day) highest seed germination was 64% from site 2 exhibited by GLMT and BLMT morphotypes on 120kg/ha fertilizer, while at site 1 had highest seed vigor at 62% by BEMS, GLMT and BLMT morphotypes on 120kg/ha fertilizer. On average lowest daily seed germination was 49% by BEMS Morphotype at site 1 on control (no fertilizer). While so, site 2 morphotypes exhibited lowest seed vigor of 50% by BEMS Morphotype with other morphotypes GEMS, GLMT and BLMT had 51% seed vigor on control treatment. The 60kg/ha fertilizer had highest seed vigor at 58% by BLMT Morphotype from site 2 and lowest being 55% by morphotypes GEMS and BEMS at site 1.

Electrical Conductivity (E.C) results

Effect of harvesting stage and N fertilizer on E.C of green pod harvested seed

E.C results indicated that all morphotypes seeds of Jute Mallow had low leachate conductivity of below 1.0 µS cm^{-1} g^{-1} meaning that seeds were of high vigor. Though so, there was significant variation ($p<0.05$) within and across morphotypes with lowest E.C being 0.08 µS cm^{-1} g^{-1} by GLMT and BLMT morphotypes on 120 kg/ha fertilizer at both site 1 and 2. The highest E.C was 0.16 µS cm^{-1} g^{-1} by BEMS and GLMT morphotypes on control (no fertilizer) at site 1. The 60 kg/ha fertilizer rate had lowest E.C at 0.09 µS cm^{-1} g^{-1} by GLMT Morphotype at both sites 1 and 2, though there where high E.C e.g. 0.12 µS cm^{-1} g^{-1} exhibited by BEMS and BLMT morphotypes at site 2, and 0.11 µS cm^{-1} g^{-1}

by GEMS and BEMS Morphotypes at site 1. Other high E.C included 0.10 µS cm^{-1} g^{-1} by BLMT Morphotype on 60 kg/ha fertilizer rate at site 1.

Effect of harvesting stage and N fertilizer on E.C of tan pod harvested seed

The E.C results of seed at tan stage showed low leachate conductivity of below 1.0 µS cm^{-1} g^{-1} meaning that seeds were of high vigor. Though so, there was significant variation ($p<0.05$) within and across morphotypes with lowest seed vigor being 0.04 µS cm^{-1} g^{-1} by morphotypes GEMS, BEMS, GLMT and BLMT on 120 kg/ha fertilizer at both sites 1 and 2. Though the highest E.C of 0.6 µS cm^{-1} g^{-1} was by BEMS Morphotype on 60 kg/ha fertilizer at site 1, still seeds were of high seed quality. Other E.C were 0.5 µS cm^{-1} g^{-1} by morphotypes GEMS on 0 kg/ha and 60 kg/ha fertilizer, BEMS on 0 kg/ha fertilizer and GLMT and BLMT on 0 kg/ha fertilizer at site 1. At site 2 E.C of 0.5 µS cm^{-1} g^{-1} were by morphotypes GEMS, GLMT and BLMT on 0 kg/ha fertilizer, and BEMS on 0 kg/ha and 60 kg/ha fertilizers.

Effect of harvesting stage and N fertilizer on E.C of black pod harvested seeds

Electrical conductivity test results showed all morphotypes seed harvested at black stage had high leachate conductivity of above 1.0 µS cm^{-1} g^{-1} indicating seeds were of low vigor. There was significant variation ($p<0.05$) within and across morphotypes with highest E.C being 2.7 µS cm^{-1} g^{-1} by GLMT Morphotype on 0 kg/ha fertilizer at site 1. Other high E.C were 2.6 µS cm^{-1} g^{-1} by BEMS and BLMT morphotypes on 0 kg/ha fertilizer (control) at site 1, 2.5 µS cm^{-1} g^{-1} by GEMS and GLMT morphotypes at site 1 and 2, respectively on 0 kg/ha fertilizer. Equally high E.C included 2.4 µS cm^{-1} g^{-1} by GEMS, BEMS and BLMT morphotypes on control (0 kg/ha) fertilizer at site 2. The lowest E.C was 1.5 µS cm^{-1} g^{-1} by GLMT and BLMT morphotypes on at site 1 and BEMS Morphotype at site 2, on 120 kg/ha fertilizer. Other low E.C included 1.6 µS cm^{-1} g^{-1} by GEMS and BEMS morphotypes at site 1 and BEMS, GLMT and BLMT morphotypes at site 2 all on 120 kg/ha fertilizer.

Discussion

Effect of harvesting stage and N fertilizer on analytical purity of Jute mallow seeds

All seeds of Jute Mallow morphotypes (GEMS, BEMS, GLMT and BLMT) harvested at green, tan and black pod seed stages showed high analytical purity (over 99%) at both site 1 and site 2. This indicated that seeds were of high quality, thereby meeting ISTA (2004) seed quality status of above 98% purity. Such high purity indicated that seeds were well processed concurring with report by Abukutsa-Onyango (2007), Ndinya, (2005) and Rutto et al. (2018) that seeds processed properly exhibit good seed quality in respect to purity. Combination effect of higher N fertilizer of 120 kg/ha and tan pod harvesting stage from both sites 1 and site 2 showed highest purity of seed (99.9%) and lowest seed purity (99.4%) on control (0 kg/ha) N fertilizer by black pod harvesting stage when both factors were used across the morphotypes. These results support findings of similar work done by Kamotho, (2004) and Rutto et al. (2018) that good agronomic practice like fertilizer use increases crop and seed quality with no dependency on the stage of harvest. This implies that seed quality improves the use of N fertilizer coupled with seed harvested at tan pod stage which is in line with the findings of Olaniyi and Ajibola (2008) that N fertilizer and other good farming practices improves crop and seed quality.

Effect of harvesting stage and N fertilizer on germination of Jute Mallow seeds

Results of seed germinations of Jute Mallow from three harvesting stages of green, tan and black pod of Jute Mallow, showed best overall performing harvesting stage in seedling germinations was tan pod stage (92.9%) from GEMS and BEMS morphotypes at site 2 on 120 kg/ha N fertilizer and 91.2% (site 1) on same fertilizer. This indicated that seeds were of high quality meeting ISTA (2004) quality status, which indicates minimum germination is above 60% concurring with results of research by MOA (2014) and Akamine et al. (2007) that N fertilizer and mature pods harvest enhance crop and seed quality. Such results indicated that N fertilizer and harvesting stages had effect on seed quality as shown by highest germination results from the three harvesting stages of tan pod (92.9%), green pod (77.9%) and black pod (59.3%) from both Site 1 and Site 2, which is in accordance with the findings of Kalro, (2016) and Moa, (2016) that applying good production practices improves seed quality, especially the germination aspect. These also agree with findings by Simiyu et al. (2003) who reported fertilizer combined with good cropping practices like timely harvesting significantly increases quality of seed and crop.

Other reports in support of this research outcome on N fertilizer response include findings of research work by Hassanzadeh et al. (2017) on effect of phenological stages on essential oil content and K'Opondo et al. (2005) results that when combined increasing N fertilizer rates and appropriate African leafy vegetable pod harvesting stages are used, there is an increase in the germinations percentage. The green pod germination (77.9%) was higher than black pod (59.3%); the seeds were not dry enough and could be damage during processing and storage, which is in line with results of previous research done by Keding, (2007).

Effect of harvesting stage and N fertilizer on seed vigour (speed of emergence)

Harvesting stage and N fertilizer affected speed of germinations of the three harvesting stages of green, tan and black pods as by the end of germination period (5^{th} day) with highest germinated seed being 91% exhibited by GLMT and BLMT morphotypes on 120 kg/ha N fertilizer concurring with findings by Ngoze and Okoko (2005) that fertilizer and timely harvest enhance seed vigour. This is evidenced by the results with best overall performing harvesting stage being tan pod stage with highest seed vigour at 93% (site 2) and 78% (site 1) supporting findings of similar work by Kalro, (2015). The variation effect by fertilizer and harvesting stages was 33% evidenced by highest germination from both sites 1and 2 being 93% exhibited by GLMT and BLMT morphotypes, while the lowest was 60% (no fertilizer) by from site 1 supporting results by Schipers, (2002) and Rutto et al. (2018) that crops subjected to good agronomic practices e.g. fertilization perform better in the respect of quality and yield.

Effect of harvesting stage and N fertilizer on E.C of Jute Mallow seeds

E.C test results from all morphotypes harvested at green and tan pod stages and higher fertilizer rates (120 kg/ha and 60 kg/ha) from both Site 1 and Site 2 had low E.C of below 1.0 µS cm^{-1} g^{-1} indicating seeds were of high vigour. Though such was observed, there was significant variation ($p<0.05$) within and across morphotypes with lowest seed vigor being 0.4 µS cm^{-1} g^{-1} and highest E.C of 0.6 µS cm^{-1} g^{-1} giving a variation over 0.2 attributed to the effect by harvest stage and fertilizer rate at both site 1 and 2. These are in line with observation by Olaniyi and Ajibola (2008) who argued that fertilized and timely harvested seed lowers E.C of seed, indicating high seed vigour. Similar results was observed in higher fertilizer (120 kg/ha) rates, exhibited by morphotypes GLMT and BLMT (0.08 µS cm^{-1} g^{-1}) and GEMS and BEMS (0.5 and 0.6 µS cm^{-1} g^{-1}) respectively, all indicating quality seeds, which is in line with results reported by Aisha et al. (2013) and Rutto et al. (2018) that fertilizer use enhances Jute Mallow crop and seed quality. Equally low

E.C by other morphotypes include; 0.09 µS cm^{-1} g^{-1} by GLMT morphotype at both sites 1 and 2, E.C of 0.12 µS cm^{-1} g^{-1} exhibited by BEMS and BLMT morphotypes at site 2, and 0.11 µS cm^{-1} g^{-1} by GEMS and BEMS Morphotypes at site 1 supporting findings by Okongo, (2005) and Kamotho, (2004) that good farming practices enhance crop and subsequent seed quality.

Black pod stage had high E.C of above 1.0 µS cm^{-1} g^{-1} meaning seeds were of low vigor. This is shown by significant variation ($p<0.05$) within and across morphotypes of 1.2% with highest E.C being 2.7 µS cm^{-1} g^{-1} by GLMT Morphotype on 0 kg/ha fertilizer rate at site 1 and lowest E.C of 1.5 µS cm^{-1} g^{-1} by GLMT and BLMT morphotypes at site 1 and BEMS morphotype at site 2. This indicated that seeds were of low quality supporting reports by K'opondo et al. (2005) and Kamotho et al. (2014) that late seed harvesting when they are at black stage lowers seed quality due to various reasons including lodging and shattering among others. The other high E.C variations were 2.6 µS cm^{-1} g^{-1} by BEMS and BLMT morphotypes on control at site 1 and 2.5 µS cm^{-1} g^{-1} by GEMS and GLMT morphotypes at site 1 and 2, respectively on 0 kg/ha fertilizer, supporting observations made by Kalro, (2015) and Rutto et al. (2018) that none fertilized seed crop have high E.C if left in field long before seed harvest as it leads to pods absorbing moisture enhancing seed deterioration. Also results by Ngoze and Okoko (2005) showed seeds forming mounds after seeds were overstayed before harvest thereby lowering seed quality.

Conclusion

It is concluded that well fertilized Jute Mallow and seed harvested when ripen pods are at tan stage increases yield and seed quality in terms of analytical purity, germination and vigor. It is recommended that N fertilized should be practiced for Jute Mallow crop and its seeds should be harvested at tan pod stage for higher seed quality and better yields.

Conflict of interest

The authors indicate no conflict of interest for this work.

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