Blueprint Academic Publishers

Journal of Crops, Livestock and Pests Management
1(2)
Received: August 29, 2023
Accepted: October 6, 2023
Published: October 23, 2023

Effect of Leaf Harvesting on Yield Parameters and Seed Quality of Kenaf (*Hibiscus cannabinus* L.)

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Abstract

Kenaf (*Hibiscus cannabinus* L.) is an African Leafy Vegetable (ALV) which has a wide range of uses but mostly known as a fibre crop as opposed to vegetable. There is limited information on the seed quality aspects of kenaf and how farmers' practices like leaf harvesting may affect the plant growth characters and yield parameters. A greenhouse experiment was set up at the University of Eldoret, Kenya, in a completely randomised design in a factorial arrangement with six leaf harvesting stages and two capsules harvesting stages in four replications. The leaf harvesting stages were 2 weeks before flowering (78 DAP), 1 week before flowering (85 DAP), at flowering (92 DAP), 1 week after flowering (99 DAP), 2 weeks after flowering (106 DAP) & no harvest (control). A standard germination test was conducted in the seed physiological lab of the University of Eldoret, Kenya, and data collected on germination percentage, seedling vigour index I, seedling vigour index II and germination velocity index (GVI). Data on yield parameters was collected on seed size, 1000 seed weight and number of seeds per capsule, and data analysed using R software. Seed number per capsule was significantly influenced by leaf harvesting ($p<0.05$) but was not affected by capsule harvesting ($p>0.05$). Leaf harvesting and capsule harvesting stage did not affect seed size ($p>0.05$). 1000 seed weight varied significantly among the capsule harvesting stages ($p=0.01031$) but wasn't affected by leaf harvesting. Highest 1000 seed weight of 18.60g was recorded from seeds in greenish yellow capsules when leaves were harvested at flowering. The germination percentage varied significantly among the leaf harvesting treatments ($p< 2.2e-16$) and stage of harvesting the capsules ($p=0.0004456$). Highest seed germination (94%) was attained in seeds obtained from greenish yellow capsules when leaves were harvested at 1 week after flowering. GVI was significantly influenced by leaf harvesting stage ($p=1.5e-06$) and stage of capsule harvesting ($p=0.00052$). Greenish-yellow capsules had seeds with higher germination velocity index than brown capsules**.** The highest germination velocity index of 17.65 was observed in seeds attained from brown capsules when leaves were harvested at 1WAF. Leaf harvesting of Kenaf significantly influenced its seed quality with harvesting at 1 week after flowering having higher seed quality. Seed harvested from greenish-yellow capsules (180 DAP) had better quality in terms of germination and vigour (GVI) compared to those harvested from brown capsules (195 DAP).

Keywords: Kenaf, leaf harvesting, capsule harvesting stage, seed quality, yield parameters

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Competing interests: The authors have declared that no competing interests exists

Introduction

Kenaf (*Hibiscus cannabinus L)* belongs to the family Malvaceae which comprises of over 200 species (Hassan *et al,* 2018; Charles *et al.*, 2002). It is an African leafy vegetable that is found in various nations in Africa including Ghana, Ivory Coast, Nigeria, Kenya, Uganda and other parts of the world. It is reported to have been first domesticated in Northern Africa (Egypt) then from there it spread to other parts of the world including China, Vietnam, Thailand, Bangladesh, India and USA (Chan & Ismail, 2009; Alexopoulou *et al.*, 2013; Adnan *et al.,* 2020; Charles *et al.*, 2002; Islam *et al.,* 2018). This crop grows in Southern Africa in nations such as Botswana, South Africa, and Swaziland in the wild or as a weed of arable lands (Zwane & Masarirambi, 2009).

The crop is utilised for various purposes ranging from food, animal feed, medicine and fibre which are sourced from its various parts. The leaves and shoots are cooked and eaten as a vegetable (Alexopoulou *et al.*, 2013), while on the other hand, both leaves and stalks are utilised as livestock and horse feed (Cheng 2016). Other plant parts have been reported to contain some functional compounds that are imperative in alleviating various ailments such as aches, fever, blood and throat disorders, anemia and diabetes, and those that are helpful in gaining weight (Lee *et al.*, 2007, Lawton, 2004, Agbor *et al.*, 2005 & Cazaroll *et a.l*, 2006).

It is a common practice by farmers to harvest Kenaf leaves throughout its growth stages but this practice may result in poor seed quality. It has been stated that leaf removal influences the growth and photosynthetic capacity of plants, and remobilizes carbon and nitrogen reserves (Iqbal *et al.,* 2012). The effect of leaf harvesting stage on the crop performance is dependent on the growth stage at which it is done (Ibrahim *et al.*, 2010). The timing of leaf harvesting affects the production of photosynthate and its distribution to other plant parts, hence affecting plant performance (Biswas, 2005; Iqbal *et al.,* 2012). Despite the importance of Kenaf in the livelihood of smallholder farmers in Africa, it has gained very little research attention and in some regions in Africa, it is underutilized and still regarded as a weed (Zwane & Masarirambi, 2009). Poor seed physiological quality has been reported in kenaf seeds (Daniel *et al.,* 2012) but this has not been associated with leaf harvesting. Owing to the fact that Kenaf is an African leafy vegetable with almost an entirely an informal seed system, farmers' practices of crop management could be very critical in determining the ultimate seed quality observed. However, the effect of one of such practices particularly leaf harvesting on seed quality has not been clearly examined, and when farmers harvest the leaves, they do not follow any systematic pattern. A study like this could provide information that will be very important in farmers training with regard to seed quality and crop performance of Kenaf. The objective of the current study was to determine the effect of leaf harvesting stage on seed germination and vigour of Kenaf seeds.

Methodology

Seed of a local Kenaf landrace was sourced from Gulu central market, northern Uganda. The seeds were cleaned and sorted to remove any impurities to obtain pure seeds that were used in the experiment. A green-house experiment was conducted at the University of Eldoret. Completely randomised design in a factorial arrangement with six leaf harvesting stages and two capsules harvesting stages in four replications was established. Seeds were sown in the 5 litre buckets spaced out at 75cm x 30cm, containing a mixture of manure, sand and topsoil in the ratio of 1:1:4. Three seeds were sown per bucket and seedlings thinned to one seedling per bucket two weeks after emergence and all recommended agronomic practices were carried out until maturity; watering once every day in the morning, top dressing urea 3g/bucket, removing weeds by hand and a morning application of 5ml/L of brigade insecticide (Bifenthrin is the active ingredient), twice in a 7 days interval. Leaf harvesting was carried out by removing 50% of the leaves on the plant in the following manner; at (2WBF) 2 weeks before flowering which was 78 days after planting, (1WBF) 1 week before flowering which was 85 days after planting, at flowering which was 92 days after planting, (1 WAF) 1 week after flowering which was at 99 days after planting, then (2WAF) 2 weeks after flowering which was at 106 days after planting and there was also a control setup where no leaves were harvested. The capsules from the aforementioned treatments were harvested at greenish yellow stage corresponding to 180 days after planting and brown stage corresponding to 195 days after planting and sun dried in brown paper bags. The capsules from each treatment were carefully opened by hand, then the seeds were separated according to their respective treatments and placed on a paper towel for counting the number of seeds per capsule. After counting, 250 seeds of replicated 4 times were weighed on a digital balance (PCB 1000-2, KERN & Sohn GmbH, D-72336, Balingen, Germany), afterwards, then multiplied by 4 to get a 1000 seed weight. Three replicates of 10 seeds were randomly picked, and each seed was individually placed between the two sleeves of a venier calliper, the length recorded in centimeters and average length of the ten seeds obtained

Fifty seeds replicated three times from the capsules harvested from each leaf harvesting stage and each seed harvesting stage were subjected to standard germination test. The seeds were surface sterilized with 1% sodium hypochlorite solution for 3 minutes, placed on two layers of moistened blotter paper in sterilised petri dishes and incubated in a germination chamber (BJPX-B40011, Biobase Biodustry (Shandong) Co. Ltd) at alternating temperatures of 20/30°C for 16hours in darkness and 8 hours in light (Ekpong, 2009; Castro *et al.,* 2014). The number of germinated seeds were recorded daily for 10 days. Final germination percentage (FGP) was calculated from

$$FGP = \frac{number\ of\ germinated\ seeds}{total\ number\ of\ seeds\ sown}\ X\ 100 \ldots\ldots Eq\ 1$$

(Shaheb *et al.,* 2015).

Germination velocity index (GVI) was calculated using the following formula by Maguire (1962);

$$\mathrm{GVI} = {}^{\mathrm{G1}}/_{\mathrm{N1}} + {}^{\mathrm{G2}}/_{\mathrm{N2}} + \ldots\ldots + {}^{\mathrm{Gn}}/_{\mathrm{Nn}} \ldots\ldots\ldots\ldots Eq\ 2$$

Where;

$\mathrm{G1}, \mathrm{G2} \ldots. \mathrm{Gn}$ are number of seeds germinated on 1st, 2nd and last count.

$\mathrm{N1}, \mathrm{N2} \ldots\ldots \mathrm{Nn}$ are number of days at 1st, 2nd and last count from the sowing day.

For seedling vigour index, I, 10 normal seedlings were randomly selected from each replicate of the germination test, seedling length measured from root tip to the shoot tip using a 30cm ruler and seedling length multiplied by final germination percentage to obtain seedling vigour index I (Abdul-Baki & Anderson, 1973; Reddy & Khan 2001). For Seedling vigour index-II, 10 normal seedlings selected randomly from each replicate of the germination test were dried at 65°C for 48 hours and the seedling dry weight measured using a digital weighing balance. Seedling vigour index II was obtained by multiplying seedling dry weight by final germination test (Abdul-Baki & Anderson, 1973; Reddy & Khan, 2001). The data were analysed using the R statistical package version 4.2.3 (R Core Team, 2023). The variables were subjected to a normality test using the Shapiro-Wilk test and for all the variables that obeyed the assumption of ANOVA, an analysis of variances was performed. For all the significantly different treatments, their means were separated using Fisher's protected LSD at a 5% level. All the graphs were drawn using the ggplot2 package in R.

Results

Seed number per capsule

This varied significantly among the leaf harvest treatments (p=1.95e-05). However, the stages of capsule harvesting (p= 0.5639) and interaction between leaf harvest treatments and stages of capsule harvesting were not significant (P=0.0979). Control and the 1WAF had the highest seed number of 21 and 20 respectively while harvesting at flowering resulted in reduced seed numbers with an average seed number of 14.6 which was the lowest as shown in figure 1.

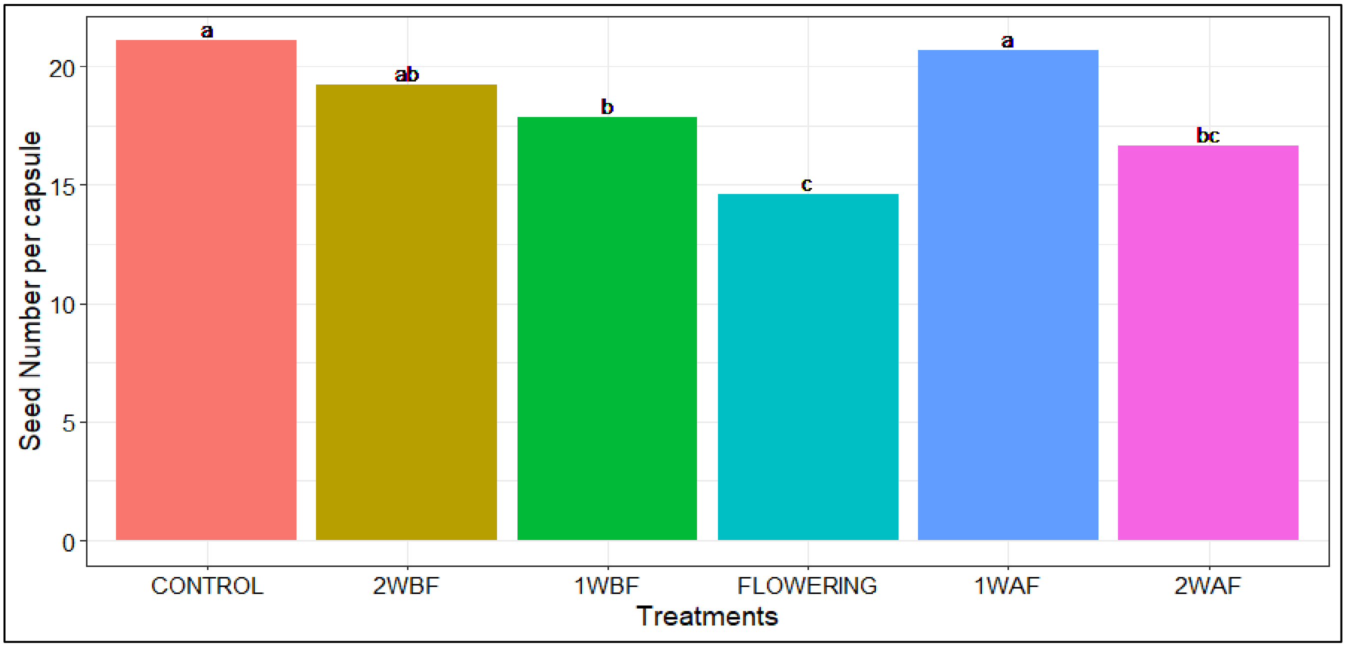

Figure 1: Shows the seed number per capsule for the different treatments

Treatments with different letters were significantly different at 5% Fisher's significance level
Whereby WBF= week(s) before flowering; WAF= week(s) after flowering

Seed size
Seed size did not significantly vary among the treatments (p=0.54358), stages of harvesting capsules (p=0.06916), and the interaction between treatments and stages of harvesting capsules (p=0.95731). The highest seed size of 3.88 cm was attained when capsules were harvested at brown stage and leaves harvested one week after flowering, while lowest seed size of 3.70cm was observed in greenish yellow capsules when leaves were harvested at flowering.

1000 seeds weight
The 1000 seed weight varied significantly between the capsule harvesting stages (p=0.01031). However, the effect of leaf harvesting stages was not significant (p=0.05596). The seeds from capsules harvested at greenish yellow stages were on average 1.00g heavier than those from brown capsules.

Table 1: Shows the effects of leaf harvesting on average seed sizes, SVI-I, SVI-II and 1000 seed weight

	SVI-I		SVI-II			Seed size		1000 seed weight	
Treatments	H1	H2	H1	H2		H1	H2	H1	H2
1WAF	737.9	656.9	10.68	5.61		3.80	3.88	16.40	16.40
1WBF	810.0	564.9	9.46	8.63		3.81	3.86	17.00	16.80
2WAF	679.3	652.0	8.89	7.87		3.79	3.78	16.80	15.20
2WBF	677.6	739.5	7.15	9.97		3.79	3.84	16.00	15.60
CONTROL	520.9	578.7	6.47	5.71		3.72	3.81	17.60	16.40
FLOWERING	723.1	725.8	7.23	6.61		3.70	3.80	18.60	16.00
Grand Total	691.5	653.0	8.31	7.40		3.77	3.83	17.07	16.07
F. Prob	0.1981		0.4219			0.54358		0.05596	

Whereby H1= seeds harvested at greenish yellow capsule stage
H2= seeds harvested at brown capsule stage

Germination percentage

The germination percentage vary significantly among the leaf harvesting treatments (p< 2.2e-16) and stage of harvesting the capsules (p=0.0004456). Seeds from capsules harvested at stage 2 (brown capsules), attained highest germination percentage of 18% on the first day when leaves were harvested from the plants one week after flowering. Seeds from Greenish yellow capsules (first harvesting stage) of those plants whose leaves were harvested at Flowering and 1WAF results in highest germination percentage of 94 by the 10th day while harvesting greenish yellow capsules in control results into lowest germination of 46% by the 10th day.

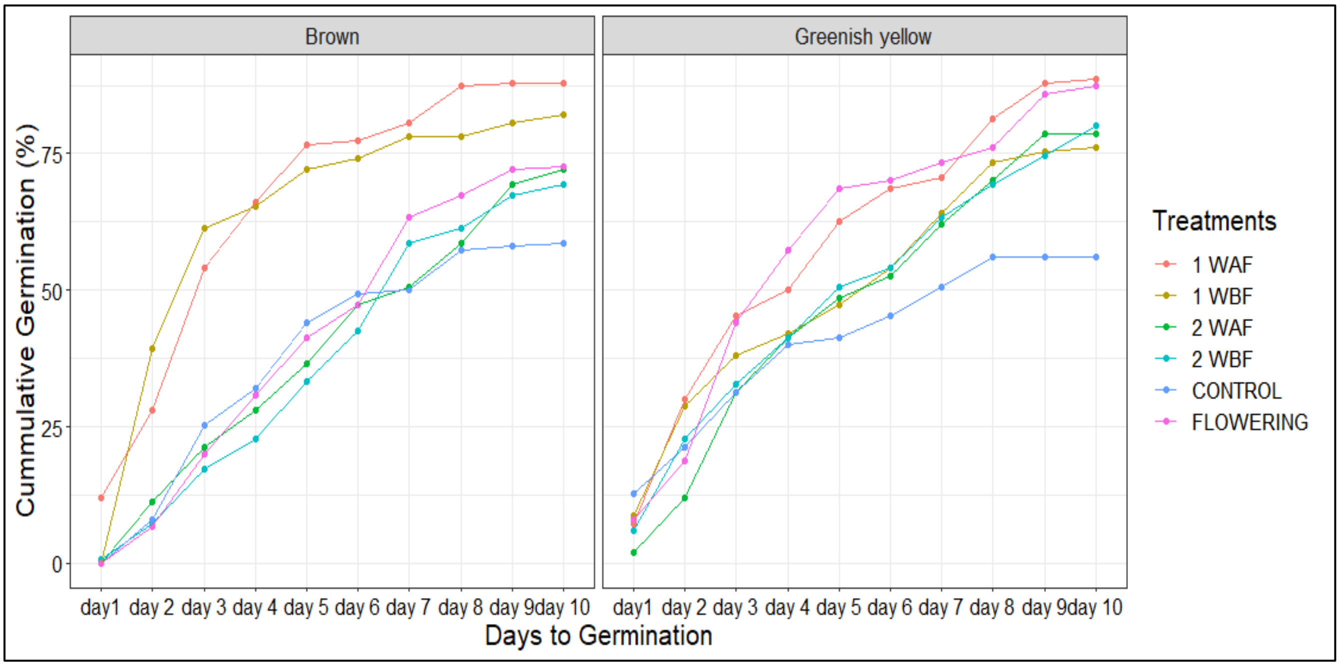

Figure 2: Graph shows the cumulative germination percentage for the different treatments for different times

Whereby WBF= week(s) before flowering, WAF=week(s) after flowering

Seedling vigour index 1: This did not vary significantly among the leaf harvesting treatments (p=0.2131), and the stage of harvesting capsules (p=0.3638). the highest SV-I was attained when leaf harvesting was done at 1WBF at the greenish yellow capsule stage, (810.0) while the lowest was at control, still at the greenish yellow capsule stage, (520.9).

Seedling vigour index 2: this also did not vary significantly among the leaf harvesting treatments (p=0.4289), and the stage of harvesting capsules (p=0.3237). The highest SV-II was attained when leaf harvesting was done at 1WAF at the greenish yellow capsule stage, (10.68) while the lowest was at the same leaf harvesting stage but at the brown capsule stage.

Germination velocity index

The germination velocity index varied significantly among the leaf harvesting treatments (p=1.5e-06), stage of capsule harvesting (p=0.00052) and the interactions between the treatment and the stage of capsule harvesting (p=0.00121). Generally, capsules harvested at green stage produced seeds with higher germination velocity index (13.34) compared to those harvested at when brown (10.97). The highest germination velocity index of 17.65 was observed in seeds attained from brown capsules when leaves were harvested at 1WAF while the lowest was 7.92 observed in seeds from brown capsules of control plants and when leaves were harvested at 2WBF (figure 3).

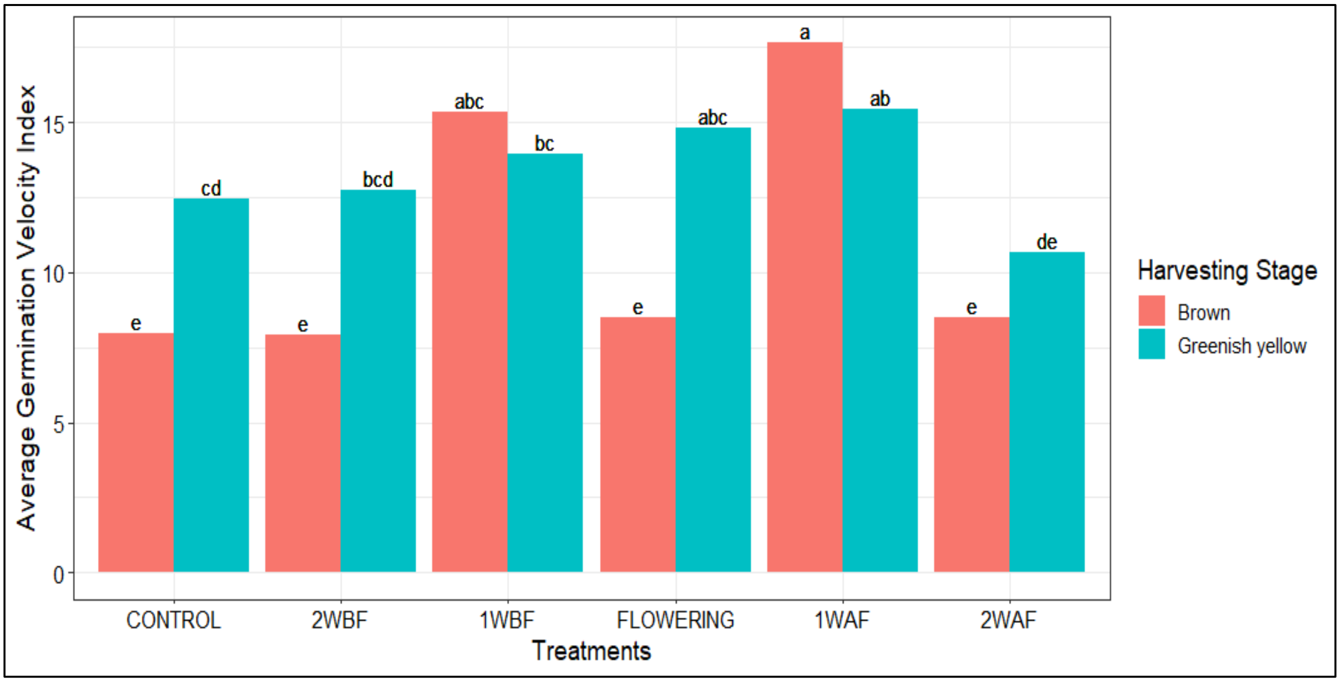

Figure 3: Shows the effects of Treatments on the germination velocity index

Treatments with different letters were statistically significant at 5% of Fisher's protected significant level. WBF= week(s) before flowering, WAF=week(s) after flowering

Discussion

Effects of leaf harvesting on the yield parameters

Seed number per capsule

Figure 1 shows that the treatment had a significant effect on the number of seeds per capsule with control having the highest number of seeds per capsule. Among the leaf harvested treatments, 1WAF had the highest although it was not statistically different from the control, but the seed number drastically declined when harvesting was done at flowering in relation to the control, this treatment had 6 seeds less than the control. These results agree with the findings of Smiderle (2017) and Islam *et al*. (2014) carried out leaf harvesting in cowpeas and soybean respectively. Another study found out that removing the leaves does not have any significant effect on seed per pods in Ethiopian mustard, (Baldwin *et al.,* 2021), which is in total contrast to the findings of this present study. It was further suggested that at 1WAF and 2 WBF plants were able to partition the less assimilates to seeds within the capsules rather than generating few seeds due to a decreased photosynthetic capacity (Demooy & Demooy, 1989), while the reverse is true when harvesting was done at flowering. (Akiyama & Agren 2012) stated that the impact of leaf removal at earlier stages in many plant species is strongly negative as compared to late stages, but this is not the case with the results from the present study as the reduction in the number of seeds at both stage (late and early) was statistically similar.

According to the results, when it comes to kenaf, the effect of leaf harvesting is more detrimental to the seed number per capsule at the flowering stage as compared to other stages of the crop growth as most of them had figures closer to the control. This outcome may be due to the removal of leaves during a period where there is a rise in the requirement of photosynthesis products for producing and filling seeds as a result of an increase in the size of sinks (Smiderle *et al.,* 2017),

When leaf harvesting was done at flowering, the number of branches were fewer than all the treatments, the effect of this was reflected on the number of seeds per capsule within the same treatment as it also produced the lowest results, so for this stage of harvest, not only did the effect of the treatment reduce the source size, it also had a negative effect on the sink production (seeds) (Mondal *et al.,* 2011). 2WAF and 1WBF had the highest number of branches as compared to other treatments but then produced lower seed per capsule as compared to others apart from 2WBF and this seemed to agree with the findings of (Ali *et al*.,2013) in soybean who stated that the reason could be due to inactive branches.

Seed weight

The results from table 1, show that there was no significant difference between leaf harvesting stages. It should be noted that seed weight is an important biological factor affecting germination percentage, germination rate and the growth of seedling (Hamza *et al.,* 2019). The plants whose leaves were harvested at flowering stage had the highest seed weight and 1g more than the highest in the control, while the lowest being 2 WAF, having 1.2g less than the lowest in control. This is similar to the findings of Vargas-Ortiz *et al.* (2013) and Baldwin *et al.* (2021) in grain amaranth and Ethiopian mustard while they entirely differ from the studies conducted by Islam (2014) and Smiderle (2017). Foliage loss in the crops did not seem to have any effect on the seed weight, this is a direct opposite of the findings of Khan and Lone (2005) who found an increment in seed weight with relation to the control due to the removal of leaves. The results from table 1 also depict that, harvesting when the capsule are greenish yellow gives slightly better seed weights than when the capsules are brown, the treatments that seemed to be affected the most are 2WAF and 2WBF both capsule harvesting stages. The reasons for lower seed weights in other growth stages may be attributed to a diminished ability of plants to produce the carbohydrates necessary for grain filling and leaf repair caused by leaf removal, (Dinssa *et al.,* 2018)

Seed size

The size of the seeds has been stated as one of the important indicators of physiological quality and it also influences the fitness of the plant as larger seeds normally give out better results than smaller ones (Giles 1990). The results in table 1 show that there was no significant effect of leaf harvesting on seed size. The seeds that were harvested when the capsules were brown gave out better sizes in general as compared to greenish yellow ones, with the highest being 1WAF (3.88cm) being 0.07cm larger than the ones in control at the same seed harvesting stage, which according to Koptur *et al.* (1996) may be due to the remaining significant number of photosynthetic tissues; leaf rachises, stipules, stems. The smaller sizes of seeds were found in greenish yellow harvested capsules when leaves were harvested at the flowering stage of the kenaf plant, the seed size was 0.02cm smaller than the control at the same capsule harvesting stage. The smaller sizes could indicate that they had smaller amount of photosynthates present in them. It has been reported that these distinct seed sizes show that the seeds have different levels of starch and other energy reserves which may be an important factor to improve the expression of germination and initial growth of seedlings (Steiner *et al*., 2019).

Germination capacity

It is imperative for seeds to reach full physiological maturity prior to harvest, so harvesting of seed crop at optimum stage of seed maturation is essential to obtain better quality and the colour of capsules could be used as an indicator of when to initiate harvest (Nogueira *et al*., 2014; Gnyandev *et al.,* 2023; Lopes *et al.,* 2014). High physiological quality has been stated as the major key cause of the initial stand, vigour of plants in the field, as well as the high crop output, (Nogueira *et al.,* 2014). The results from figure 2, depict that the treatment had a significant effect on the germination. The greenish yellow capsules from plants whose leaves were harvested at flowering and 1WAF resulted in higher seed germination percentages (94%) and were higher than the control by 48% in the same category, these results agree with (Heidari, 2015) but contradict the findings of Emine *et al.* (2007) and Koptur *et al.* (1996) in maize and common vetch respectively. When it comes to seed harvesting stages, the results are in conformity with the findings of Shaheb *et al.* (2015); Begun *et al.* (2022) and Gnyandev *et al.* (2023) in French bean, Okra and Soybean respectively. Heidari (2015) stated that as a survival mechanism, seeds of leaf harvested crops tend to produce higher germination percentages and this is reflected in this study as all the leaf harvested treatments in both seed harvesting stages had higher germinations as compared to the control. These results suggest that seeds from plants whose leaves were harvested at 1WAF and at flowering used their reserves more competently than those from other leaf and seed harvesting stages. This is supported by Shahi *et al.* (2015), as they indicated that the germination relies on the capability of the seeds to use their reserves effectively. Moreover, harvesting at the greenish yellow capsules (180 DAP) could be seemed to produce much better germination percentages as opposed to when they were brown (195 DAP), and this may indicate that it is the stage of physiological maturity.

Germination velocity index, SVI-I &SVI-II

Stored food reserves have been reported to play a crucial role in seed vigour (Wen *et al.,* 2018). The results in figure 3, show that leaf harvesting has a positive influence in germination velocity index as most of the treatments responded with better values than that of the control (plants whose leaves were not harvested). The highest GVI was observed at 1WAF (brown capsules), which was 9.73 higher than the control (brown capsule). For leaf harvesting stages, these results are in contrast with the results of Koptur *et al.* (1996) in common vetch while when it comes to seed harvesting stages the result conform to those of Nogueira *et al*. (2014) in cowpeas. Multiple studies have reported that seed sizes can influence the germination parameters such as GVI (Zareian *et al*. 2013; Souza & Fagundes *et al.,* 2014 & Hamza *et al.,* 2019) but for this present study, the seed weight and size could not be used as the explanation for the result as they were all statistically similar. So, the result of high and low GVIs could be due to the ability the individual seeds at different leaf harvesting stages and seed harvesting stages to absorb water efficiently and to trigger those process that are necessary for germination. The same applies for the SVI-I and SVI-II, as Milosevic *et al.* (2010) supported the above statement that both seed weight and size are known to greatly influence seedling vigour, so that could be reason for the results in table 1, regarding seedling vigour index I and seedling vigour index II. However, in maize, it was reported that the high values of vigour could be attributed to the leaves containing a large number of nitrogen and other essential nutrients for seed filling period (Heidari 2015)

Conclusion and recommendation

The study was conducted to test the effect of leaf harvesting on seed quality and some selected yield components. Leaf harvesting proved to have a significant effect on the seed quality with the crops subjected to harvesting at 1 week after flowering having higher seed quality. The leaf harvested treatments gave out statistically similar results to the control (no harvest) in most of the yield components. Harvesting the seed at two different stages had a significant effect on the seed quality, seeds from the greenish-yellow capsules (180 DAP) had better results compared to those from the brown capsules (195 DAP). A similar study on kenaf should also be done as a field experiment to further expound on the findings of this study.

Acknowledgement

This study was funded by Intra-Africa Academic Mobility Scheme of the European Union under the Scientists in Crop Improvement for Food Security in Africa (SCIFSA) project.

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