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Interactive Effects of Moisture Content and Packaging Material on Common Bean Seed Yield and Yield Components

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Common bean (*Phaseolus vulgaris* L.) provides nutritional, economic and health benefits. Ghana has introduced the first four commercial varieties for adoption. Maintaining seed quality in storage is challenged in the humid regions due to high temperature and high relative humidity. The study determined the interactive effects of seed moisture content (MC) and packaging material on quality of seeds stored for 8 months and subsequent seed yield and yield related components. A 2x2 factorial in Randomized Complete Block Design (RCBD) was used, replicated three times. Seeds were dried to 8 and 11% MC, kept in polythene bags and plastic containers and stored for 8 months under ambient and cold conditions. There were no significant differences (p>0.05) for plant stand at two weeks after planting, days to first and fifty percent flowering, chlorophyll content, number of pods per plant, number of seeds per pod, and seed yield. Leaf area index of plants developed from seeds dried to 8% MC and packed in polythene bags were significantly higher than the other interaction effects. The lowest plant stand was observed in plants developed from seeds

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dried to 11% MC and packed in plastic containers. 1000SW of seeds dried to 11% MC and packaged in plastic containers were 32.77% higher than in seeds dried to 8% MC and packaged in plastic containers. The *Ennepa* common bean seeds can be dried to 11% MC and packaged in polythene bags and stored for 8 months without significant seed deterioration.

Keywords: Moisture content; plastic containers; polythene bags; seeds.

1. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is consumed for its nutritional quality providing dietary protein, and health benefits against major non-communicable diseases like cardiovascular, cancers and others [1,2]. Ability to harvest at various stages of growth as food provides early income for households whilst waiting for long duration crops to mature [3]. Inter-cropping with other crops also provides sustainable land use through soil fertility improvement via nitrogen fixation [3].

Crop productivity which is measured in terms of yield (seed or biomass) per unit area is largely dependent on plant population. Among the key attributes that farmers look for in the adoption of common bean cultivars include yield and storability [4]. The quality of seeds planted will determine the plant establishment in terms of germination, seedling vigour and resistance to other environmental stresses and consequently crop yield [5,6]. Differences in seed quality lead to differences in the rate of seedling emergence and canopy establishment, which result in weed suppression. If the seed germination is not uniform, the seedlings that emerge first would shade those that emerge later. Efficient resources utilization including water use efficiency, nutrients and solar radiation use, will lead to faster initial growth, better competitive ability and higher crop yields [5,7]. There is evidence that low seed vigour variations in common bean result in yield losses of nearly 20% [7]. The impact of seed vigour variation is manifested through reduced seedling emergence and plant development and subsequently, crop yield [8].

Storability of seeds is an important determinant of crop productivity. For example, the yield of common bean seeds stored between 9 and 45 months showed decreases due to seed quality deterioration with age resulting in cell membrane degradation. The highest grain yield was obtained in seeds stored for short period (9 months) in an ambient condition irrespective of cultivar and plant population [9]. Moisture content and packaging material used before seed storage is very critical in maintaining the seed quality in storage. At physiological maturity, the moisture content (MC) of common bean seed ranges between 17-58%, a situation which pre-disposes the seed to deterioration if not well managed [10]. Lower seed moisture content reduces respiration and fungal infection and consequently maintains good vigour and viability [11-15]. The longevity of seeds apart from drying, genetic factors and storage environment are also determined by the type of packaging material [9]. Generally, seed deterioration can be managed effectively by storing very dry seeds in suitable hermetic containers under ambient conditions [16,17]. In southern Ghana, characterized by high temperature and high relative humidity, seeds deteriorate faster than in areas where this condition does not exist. The objective of the study was to determine the interactive effects of moisture content and packaging material on the seed yield and yield components of the common bean variety *Ennepa* after 8-months in storage in the humid region of Ghana.

2. MATERIALS AND METHODS

2.1 Seed Source and Seed Multiplication

Seeds of the common bean cultivar *Ennepa* (white seeded) were obtained from the Council for Scientific and Industrial Research-Crops Research Institute (CSIR-CRI) in Ghana. A seed multiplication field was established in May 2019 by applying glyphosate to control the weeds, followed by ploughing and harrowing. Planting was done at the spacing of 60 cm x 20 cm with three seeds sown per hill which was thinned to 2 seedlings per hill after two weeks. Fertilizer (NPK 15:15:15) was applied two weeks after planting at the rate of 125 kg/ha. All other good agronomic practices including manual weeding, insect control, rouging and timely harvesting at maturity were done. Manual threshing was done and the seeds were cleaned and sorted for drying, packaging and storage.

2.2 Sample Preparation

One set of each seed lot (50 kg) was dried to 11% moisture content and the other set (50 kg) dehumidified (dried) to 8% moisture content using a Munter's model MX 1500E dehumidifier. One-half of the seeds dried to 11% and 8% MC were packaged in moisture-proof polythene bags, (10 cm × 10 cm and 0.2 mm thick) and heat-sealed and the other half packed in plastic containers (0.75 mm thick, 8.4 cm in diameter and 17.5 cm in height). A set of four treatment combinations (seeds dried to 8% MC and packaged in plastic container, seeds dried to 11% MC and packaged in plastic container, seeds dried to 8% MC and packaged in polythene bags and seeds dried to 11% MC and packaged in polythene bags) were stored in a warehouse constructed for ambient seed storage at 27-32 °C for 8 months. Another set of the same four treatment combinations were also stored in a cold room (15 $\pm$ 2 °C) for the same 8 months.

2.3 Description of Field Trials

The study was conducted at four locations namely Fumesua, Kwadaso, Akomadan and Mampong.

At Fumesua, the field trial was established at the CSIR-Crops Research Institute research field (317 masl N 06° 42.817'. W001°31.869') in the Forest Agro-Ecological zone. The soils in the area are Ferric acrysol [18], sandy loam and inherently low in fertility and moisture retention. It has a bimodal rainfall pattern with annual average of 1255 mm in 2020. The mean annual temperature is 27°C.

At Kwadaso, the field experiment was carried out at the CSIR-Crops Research Institute research field (245 masl N 06° 40. 696. W001 40. 321°) in the Forest Agro-Ecological zone. The soils are Haplic Lixisol [18] and sandy loam. It also has bimodal rainfall with annual rainfall of 1450 mm, and mean annual temperature of 26.73°C.

At Akomadan, the study was conducted at the CSIR-Crops Research Institute research field (319 masl N 07° 25.191. W001°58.405') in the Forest-Transition zone. The soils belong to the Ferric Lixisol [18]. The location has a mean annual rainfall ranging between 700 and 1200 mm. The mean annual temperature was 27.79°C.

At Mampong, the trial was established at the Grains and Legumes Development Board foundation seeds production field (370 masl, N 07° 25.9. W 001°02 58.3'). The soil is largely loamy sand and belongs to the Chromic Lixisol [18]. The area falls in the Forest-Transition zone. Mean annual rainfall is between 800 and 1500 mm and is bimodal and fairly distributed. The mean annual temperature is 27.34°C.

2.4 Trial Set-Up and Procedure

The experiments were laid out in a 2×2 factorial in randomized complete block design for the field trials. The factors were: two levels of moisture content (8 and 11%), and two types of packaging material (polythene bags and plastic containers), each replicated three times.

An experimental plot consisted of 4 rows, each measuring 5 m with row spacing of 60 cm, within row spacing of 20 cm and three seeds planted and thinned to two seeds per hill after two weeks, giving target plant population of 166,667 plants per hectare. Weeding was done manually using hoe. Spraying of insecticide against field insects was done using Sympirifos at the rate of 50 ml per 15 L knapsack sprayer. Fertilizer, NPK 15:15:15 was applied at the rate of 125 kg/ha two weeks after planting (WAP) when there was enough soil moisture. Harvesting was done when the leaves and pods have turned brown at harvest maturity.

2.5 Data Collected

2.5.1 Seed vigour traits

At the end of the eight months storage period, the seeds were tested for viability and vigour before planting.

2.5.1.1 Germination test

Three replicates of 50 seeds were set in moist river sand (sterilized by heating at 105 °C for 24 h) in 30 cm diameter trays and kept in polythene bags (to reduce moisture loss) at 27-32 °C. The first and final germination counts were made on 5^{th} and the 9^{th} days after the seeds were set. Seeds were considered germinated if the seedlings were normal as described by [19].

2.5.1.2 Seedling vigour

Seedling vigour was determined by multiplying the germination percentage by seedling dry matter. Thus, seedling vigour = germination (%) x seedling dry weight (g).

2.5.1.3 Tetrazolium test

The living tissues of the seed's embryo were stained using 2,3,5 triphenyl tetrazolium chloride

(TTC), after soaking 50 seeds per replica in 100 ml water in Petri-dishes for 24 h at room temperature (26 °C). One hundred milliliters (100 ml) of 1% (w/v) TTC solution in distilled water was added to each set of 50 seeds in a Petri-dish after the testa had been removed. The seeds were held in the dark for 3 hours at 30 °C. In living tissues, the TTC reacts with the dehydrogenase enzymes in the cotyledons to produce a red stain called formazan. Tissues of the cotyledons damaged during imbibition remain unstained. Cotyledons were then categorized as (1) x=100, (2) 100>x>50, (3) 50>x>1 or (4) 0% stained, where x stands for the extent of staining of each embryo. The percentage of each category was calculated for each experimental treatment [20].

2.5.1.4 Electrical conductivity test

Electrical conductivity test as a measure of seed membrane integrity and vigour was measured at the end of the storage period. It was measured in 100 ml deionised water used to soak 3.5 g of each seed lot for 24 hours into which cell content of the seed embryo had leached. The measurement was done under laboratory condition (with a mean temperature of 26 °C), using the conductivity meter-dip cell. This instrument measures the electrical current passing through the water as a result of the leakage of electrolytes from weak or damaged embryonic cells into the surrounding water. The measurement was expressed in micro-seconds per centimeter per gram of seed ($\mu S\ cm^{-1}\ g^{-1}$) [20].

2.5.1.5 Determination of phosphorus content

The content of Phosphorus (P) in the seed leachate was estimated as additional measure of vigour of the common bean seed at the end of each storage period. For phosphorus estimation, 5 ml of the seed leachate from each seed sample, together with blanks and standard series were pipetted into test tubes, after which 10 ml of color reagent was added slowly and mixed. A pinch of L-ascorbic acid was added and thoroughly mixed. Absorbance was measured with 10 mm Ø cuvettes at 880 nm after 30 min, but within 24 hours with a spectrophotometer. A graph relating the absorbance to the amount of phosphate present was plotted, and P estimated as a product of sample extract in ppm and extracting ratio. The estimation was expressed in milligram phosphorus per kilogram of seed [20].

2.5.1.6 Determination of potassium content

The amount of potassium (K) was determined by the flame photometry by comparing the intensities of radiation emitted by K atoms in the seed leachate to series of standard solutions. Seed samples were weighed and 3.5 g, put into 250 ml glass bottles and 100 ml of deionized water added. The bottles and their contents were incubated for 24 h and then filtered through a fine filter paper. Extracts were taken to the flame analyzer and the emission readings taken. A calibration curve of K-emission against concentration was plotted. Potassium was estimated as the product of sample in ppm of the extracting ratio. Potassium extract content was expressed in milligram of potassium per kilogram of seed (mg K/kg) [20]. The storage experiment was designed using 2x2 factorial in completely randomized design with 3 replications.

2.5.2 Field data

The following data were collected on plants from the two central rows during the growth and development of the common bean plant in the field.

2.5.2.1 Plant stand

The number of plants within the two central rows was counted at two weeks after planting and at harvest.

2.5.2.2 Plant height

The height of ten (10) randomly selected plants within the two central rows were measured from the soil level to the topmost leaf axil of the main stem using a tape measure. The mean value was recorded in centimeters at two and four weeks after planting.

2.5.2.3 Days to first flowering

The number of days it took for the first flower to open on the ten selected plants was recorded.

2.5.2.4 Days to 50% flowering

The number of days it took for 50% of the ten selected plants to flower was recorded.

2.5.2.5 Chlorophyll content

The chlorophyll content of the ten selected plants was measured with SPAD-502 plus Chlorophyll Meter (Konica Minolta, Inc, Made in Japan). The means were then recorded.

2.5.2.6 Number of branches per plant

The number of branches produced by the plants was determined by counting the number of branches on the ten selected plants at 4 weeks after planting. The mean was expressed on per unit basis.

2.5.2.7 Leaf area index

This was taken at 4 weeks after planting on the ten selected plants per plot using the leaf area meter. The mean was expressed on per unit basis.

2.5.2.8 Number of pods per plant

The total number of pods of the ten selected plants was counted at harvesting and the mean recorded per plot.

2.5.2.9 Number of seeds per pod

The total number of seeds per pod was recorded from the ten selected plants at the time of harvesting and the mean recorded per plot.

2.5.2.10 Thousand seeds weight

Thousand seeds were counted manually and the weight measured using an electronic balance in grams after drying to 12% seed moisture content.

2.5.2.11 Seed yield (kg/ha)

After drying seeds harvested from the two central rows to 12% moisture content, sorting was done to get physically pure seeds and the weight measured using an electronic balance. The seed yield was determined using the formula:

$$\text{Seed Yield} = \frac{\text{Seed weight (kg)} \times 10000\text{m}^2}{\text{Harvested area}}$$

2.5.2.12 Soil analyses of the trial locations

Soil samples from the locations where the trials were conducted were taken prior to planting in order to determine the soil properties.

2.6 Economic Analysis of the Two Storage

Data on the charges for storing seeds in the ambient and cold conditions were obtained from the operators for economic analysis covering the storage duration.

2.7 Data Analyses

Data analysis was performed using Statistix 9.1 statistical software package. Tukey's Honestly Significant Difference (HSD) test was used to separate treatment means in both the laboratory and field studies. Pearson's correlations among plant establishment and growth parameters were also determined.

3. RESULTS

3.1 Viability and Vigour Traits of Stored Seeds

Viability and vigour traits were determined at the end of the eight month storage before seeds were planted on the field. There were no significant differences in the germination and tetrazolium percentage after 8 months in storage (Table 1). The lowest germination percentage was recorded in seeds dried to 8% MC and packaged in plastic containers (94%) and the highest (98%) was recorded in seeds dried to 8%MC and packaged in polythene bags. There were no significant differences of the treatment combination on the electrical conductivity (EC) of the seeds after the 8 months storage period. However, there were significant interactive effects on the P and K leachates as well as the seedling vigour after 8 months in storage. After eight months in storage, the lowest level of P leachate occurred in seeds dried to 8% MC and packed in the plastic containers. Seeds dried to 8% MC and packed in the polythene bags leached 1.50 times more P than those recorded in seeds dried to 8% MC and packed in the plastic containers. After eight months storage period, seeds dried to 8% MC and packaged in the plastic containers leached significantly lower amount of potassium iron, which was 21.03% far less than the highest amount observed in seeds dried to 8% MC and packaged in the polythene bags.

3.2 Initial Soil Physical and Chemical Properties of the Trial Locations

Soil texture ranged from sandy loam at Fumesua and Kwadaso to sandy clay loam at Akomadan, and loamy sand at Mampong. The soil fertility was generally low characterized by low organic matter, nitrogen, calcium, magnesium, potassium and phosphorus contents across the four locations. In addition, all the soils were acidic with pH values of less than 5.5 (Table 2).

3.3 Comparison of Cost of Storage under Ambient and Cold Conditions

The cost of storage of 1 metric ton common bean seeds under the ambient condition was \$5/month, whereas that of the cold storage was \$10/month. Thus, for the eight month storage period, the cost was \$40 and \$80 for the ambient and the cold conditions, respectively. Percentage loss in germination of seeds stored under the ambient and the cold conditions were 5% and 3% respectively, representing \$66.67 and \$40.00 loses. Comparing the two storage conditions, it is more economical to store common been seeds under the ambient condition. Unlike the ambient storage, breakdown of the cold system due to frequent power outages poses high risk in maintaining seed quality in storage.

3.4 Seed Yield and Yield Related Traits

There were no significant differences (p>0.05) among the treatment interactions for plant stand at two weeks after planting, days to first flowering, days to fifty percent flowering, chlorophyll content at 4WAP, plant height and number of branches at 4WAP, number of pods per plant, number of seeds per pod and seed yield per hectare (kg/ha) at all the locations. However, there were significant differences in leaf area index, plant stand at harvest, and thousand seed weight (1000SW).

3.4.1 Leaf area index (LAI) at four weeks after planting

The leaf area index of plants developed from seeds dried to 8% MC and packed in the polythene bags was the highest, 18.38% significantly higher than plants developed from seeds dried to 11% MC and packed in the plastic containers which was the lowest among the treatments (Table 3). There was also a significant difference between the packaging materials, such that the leaf area index of plants developed from seeds packed in the polythene bags was 1.11 times higher than the leaf area index of plants developed from seeds packed in the plastic containers.

3.4.2 Plant stand at harvest (m^{-2})

Plant stand of plots planted to seeds dried to 8% MC and packed in the polythene bags was significantly higher than the other interactions (Table 4). The lowest plant stand was observed in plots planted to seeds dried to 11% MC and packed in the plastic containers. Between the seed moisture contents, plots planted to seeds dried to 8% MC was 1.45 times higher than the plots planted to seeds dried to 11% MC (Table 4).

3.4.3 Thousand Seed Weight (1000SW)

Thousand seed weight of seeds dried to 11% MC and packed in the plastic containers was significantly heavier than the other treatment interactions (Table 5). The lowest 1000SW was observed in seeds dried to 8% MC and packed in the plastic containers. Seeds dried to 11% MC and packed in the plastic containers were 32.77% heavier than the lowest, which was recorded in seeds dried to 8% MC and packed in the plastic containers. Between the seed moisture contents, 1000SW of seeds dried to 11% MC was significantly higher, 1.18 times heavier than those dried to 8% MC (Table 5).

3.4.4 Pearson’s correlation among plant establishment and growth parameters

The Pearson’s correlation analysis revealed that days to first flowering had fairly strong positive relation with fifty percent flowering (r=0.77, p<0.001). Additionally, leaf area index and chlorophyll content index also had weak positive correlation (r=0.42, p<0.05). The plant height at 4 weeks after planting had strong positive correlation with plant establishment at 2 weeks after planting (r=0.62, p<0.01). Similarly, plant height at 4 weeks after planting recorded significantly weak positive relation with leaf area index (r=0.42, p<0.05).

4. DISCUSSIONS

4.1 Leaf Area Index (LAI) at Four Weeks after Planting

At Mampong, the LAI of plants developed from seeds dried to 8% MC and packaged in polythene bags was 18.38% higher than the lowest value observed in plants developed from seeds dried to 11% MC and packaged in plastic containers. Leaf area is much related to the mobilization of resources for plant development and thereby affected by the vigour of the seed planted and the seedling that emerges. Although plastic containers are impervious, when used to pack seeds with initial moisture content it becomes detrimental to seed quality. Response

Table 1. Interactive effect of seed moisture content x packaging material on viability and vigour traits of common bean after 8 months in storage

Treatments	Viability Traits		Vigour Traits			
	Germination (%)	TZ (%)	EC (μscm^{-1})	P Leachate (ppm)	K Leachate (ppm)	Seedling vigour
M1P1	94.00	99.33	129.26	138.07	2039.30	188.20
M1P2	98.00	100.00	171.26	207.63	2582.50	185.93
M2P1	96.00	99.33	128.19	170.94	2209.20	221.60
M2P2	96.33	99.33	180.82	165.91	2117.40	154.00
Mean	96.08	99.50	152.38	170.64	2237.10	187.43
CV	5.31	1.20	24.01	0.78	1.02	18.96
HSD	8.562	2.006	61.412	2.221	38.244	59.637

M1= 8% moisture content, M2 = 11% moisture content, P1= Plastic containers, P2 = Polythene bags, TZ =Tetrazolium test, EC= Electrical conductivity, P = Phosphorus, K = Potassium

Table 2. Soil fertility analyses from the various common bean production locations

Location	pH 1:2.5	% 0.C	% N	% O.M	Ca me /100g	Mg me /100g	K me/ 100g	Na me/ 100g	Ex. Acidity me/100g	E.C.E.C me/ 100g	T.E.B me/ 100g	% B.S	P mg/kg	% Sand	% Silt	% Clay	Texture
Kwadaso	4.9	0.48	0.12	0.83	2.80	1.22	0.14	0.02	0.70	4.88	4.18	85.13	43.04	72	10	18	Sandy Loam
Akomadan	4.9	0.56	0.12	0.96	2.13	1.60	0.16	0.03	0.75	4.67	3.92	83.94	16.85	64	10	26	Sandy Clay Loam
Mampong	4.3	0.32	0.05	0.55	2.34	1.70	0.44	0.03	1.05	5.56	4.51	81.10	17.01	84	6	10	Loamy Sand
Fumesua	5.3	0.56	0.12	0.96	4.47	0.85	0.31	0.02	0.50	6.15	5.65	91.87	195.59	72	14	14	Sandy Loam

O. C = Organic Carbon, N = Nitrogen, Ca = Calcium, Mg = Magnesium, K = Potassium, Na = Sodium, Ex = Exchange, E.C.E.C = Exchangeable Cation Exchange Capacity, T.E.B = Total Exchange Base, B.S = Base Saturation, P = Phosphorus

Table 3. Interactive effects of seed moisture content and packaging material on leaf area index at four weeks after planting at Mampong

	Packaging material		
Seed moisture content	Plastic containers	Polythene bags	Mean
8%	115.05	125.94	120.50
11%	106.39	120.37	113.38
Mean	110.72	123.16	

HSD (0.05) for seed moisture content = 8.312, packaging material = 8.312, seed moisture content x packaging material =15.923.

Table 4. Interactive effects of seed moisture content and packaging material on plant stand (m^{-2}) at harvest at Mampong

	Packaging material		
Seed moisture content	**Plastic containers**	**Polythene bags**	**Mean**
8%	12.42	14.17	13.29
11%	8.11	10.22	9.17
Mean	10.26	12.20	

HSD (0.05) for seed moisture content =2.219, packaging material =2.219, seed moisture content x packaging material= 4.251.

Table 5. Interactive effects of seed moisture content and packaging material on thousand seed weight (g) at Kwadaso

	1000SW		
	Packaging material		
Seed moisture content	**Plastic containers**	**Polythene bags**	**Mean**
8%	170.00	180.13	170.57
11%	220.57	180.87	200.72
Mean	190.78	180.50	

HSD (0.05) for seed moisture content =2.675, packaging material =2.675, seed moisture content x packaging material =5.125.

Table 6. Pearson's correlation among plant growth parameters and seed yield of common bean variety *Ennepa* after storage

	Plants 2WAP	Days to First flowering	Days to 50% flowering	Chlorophyll Content 4WAP	Leaf area index	Plant height 4WAP	Branches 4WAP	Seed yield
Plants 2WAP	1							
Days to First flowering	0.02	1						
Days to 50% flowering	0.16	0.77***	1					
Chlorophyll Content 4WAP	0.23	0.06	0.11	1				
Leaf area index 4WAP	0.26	0.00	0.13	0.42*	1			
Plant height 4WAP	0.62**	0.07	0.33	0.18	0.42*	1		
Branches 4WAP	-0.18	-0.34	-0.33	0.19	0.06	-0.04	1	
Seed yield	0.29	-0.16	-0.20	0.21	0.05	0.102	-0.15	1

,, *** Significant at $P < 0.05$, 0.01 and 0.001, respectively.*

of seed quality in different packaging materials and storage periods differ due to the fact that depletion of oxygen in the plastic leads to release of carbon dioxide (CO_2) during respiration, which are unable to exit and thereby become toxic after increase in level of concentration [21].

4.2 Plant Stand at Harvest (m^{-2})

Poor seedling vigour impacts on the plant stand at harvest as less vigorous seedlings succumb to harsh environmental conditions leading to death of such seedlings thereby reducing the plant population which has direct effect on yield [9,22]. Plant stand at harvest was influenced by the initial moisture content and packaging material at Mampong, with plants developed from seeds dried to 8% MC recording 1.45 times more plants than the 11% MC (Table 4). Seed aging results in loss of viability and vigour which intend affect the plant stand. Slowing down this rate of deterioration includes drying seeds to low moisture content, inherent ability to store long, storing under low temperature and relative humidity conditions, and packaging seeds of low moisture content in impervious materials [5,23-25].

4.3 Thousand Seed Weight (1000SW)

At Kwadaso, plants developed from seeds dried to 11% MC and packaged in plastic containers had 32.77% greater 1000SW than the least found in plants developed from seeds dried to

8% MC and packaged in plastic containers. The lower 1000SW recorded with plants developed from 8% MC could be due to reduced plant growth and resources utilization associated with imbibitional damage (of seeds with cracks in the seed coat) and slow membrane repair. The period of membrane repairs is shorter for seeds with high moisture content than those of low moisture content [26]. The variation observed could also be due to the influence of the factors in preserving seed nutrient reserve in storage to produce vigorous seedlings on the field leading to good seed filling [27-30].

4.4 Correlation of Seed Yield and Yield Related Components of the Common Bean Variety *Ennepa*

Days to first and fifty percent flowering are very important in ensuring that plants reach maturity uniformly. Delays in these traits can result in low crop yield as harsh environmental condition for instance drought can set in and affect the plant growth. The positive correlation observed in the current study is an indication that early flowering will result in early pod setting. Additionally, leaf area index and chlorophyll content index also had weak and positive correlation. These traits are important with regards to resource mobilization for plant growth and development. Expanded leaves are able to intercept sunshine for conversion of soil nutrients through photosynthetic activity and plant nutrient supply, leading to bean seed development and crop productivity. A similar relation in common bean has been reported by Yeboah *et al*., [31]. The plant establishment (population) at 2 weeks after planting had strong positive correlation with plant height at 4 weeks after planting which also recorded significantly weak and positive relation with leaf area index. These traits have all been found to positively influence crop yield and productivity. For instance, plant establishment which translate into plants harvested have direct relation with crop production and yield [20,32]. A decrease in plant establishment will mean less competition for soil nutrient leading to vigorous plant growth as corroborated by Cardoso *et al* [33] and Ozer [34].

5. CONCLUSION

This study revealed that all the treatment combinations maintained the seed viability and vigour traits of the common bean variety *Ennepa* at high level at the end of 8 months in storage. However, based on the cost associated with drying and packaging materials it is recommended that the seeds be dried to 11% MC and packaged in polythene bags and stored for 8 months period in the humid region of Ghana. This will not only maintain the seed quality but will also increase the profit margin of seeds stored under ambient condition. The information emerging from this study will guide seed regulatory agencies, seed producers and seed marketers in drying seeds to 11% moisture content and storing it for a period of eight months whiles maintaining the quality of seed in the humid region of Ghana.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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