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Research article

Improvement in cowpea variety *Videza* for traits of extra earliness and higher seed yield

Innocent Kwaku Dorvlo [b], Godwin Amenorpe [a,b,*], Harry Mensah Amoatey [b], Samuel Amiteye [b], Jacob Teye Kutufam [a], Emmanuel Afutu [c], Elvis Asare-Bediako [c], Alfred Anthony Darkwa [c]

[a] Biotechnology and Nuclear Agricultural Research Institute (BNARI), Ghana Atomic Energy Commission (GAEC), Accra, Ghana

[b] Department of Nuclear Agriculture and Radiation Processing. School of Nuclear and Allied Sciences, College of Basic and Applied Sciences, University of Ghana, Accra, Ghana

[c] Department of Crop Science, School of Agriculture, College of Agriculture and Natural Sciences, University of Cape Coast, Cape Coast, Ghana

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ABSTRACT

The cowpea variety *Videza*, which was used as the control, matures early (70 days after planting), although it produces low yields. Gamma irradiation mutagenesis was used to induce *Videza* into extra-early maturing and higher yielding mutant genotypes. A single seed descend population was developed for radio-sensitivity test, and a Lethal Dose 50 (LD_{50}) of 240.5 Gy was determined, and applied from a cobalt-60 (^{60}Co) source, to acutely mass irradiate 1800 *Videza* seeds, at the Ghana Atomic Energy Commission. The irradiated seeds (M1) were planted to produce M2 seeds bearing plants and subsequently advanced to M3 plants for selection of nine induced plants based on extra earliness and significantly higher seed yields than the parental control. It took 48 days after planting (DAP) for the genotype coded P1N02#1 to reach 50 % maturity followed by 52 DAP for genotypes with codes P4N03#3; P3N01#5; P5N05#6, P4N14#7, P5N07#8, P5N05#10 and 54 DAP for genotype P4N14#11. P1N06#9 had the highest yield (97.38 g/plant), followed by P5N05#10 (95.97 g/plant), P1N08#13 (81.24 g/plant), P2N09#12 (73.94 g/plant), P6N10#19 (70.83 g/plant), P1N06#20 (65.36 kg/plant), P5N07#14 (61.23 g/plant), P4N14# (58.05 g/plant) and P1N08#17 (56.23 g/plant). M3 seeds were advanced to M4 plants for a Preliminary Yield Trial which revealed that induced plants P5N05#10 (1235 kg/ha), P2N09#12 (1206 kg/ha), P5N07#14 (1185 kg/ha), P1N06#20 (1171 kg/ha), P1N06#9 (1051 kg/ha), P1N08#13 (1041 kg/ha), and P6N10#19 (999 kg/ha) outperformed the control (517 kg/ha) and two other commercial varieties. Overall, the two highest performing candidates for further evaluation for varietal release were P5N05#10 and P2N09#12.

1. Introduction

Cowpea [*Vigna unguiculata* (L) Walp] is a native of West Africa, where numerous wild species are found (Ng, N., 1995; Fatokun et al., 2018). Because of its nutritional importance, cowpea cultivation is common in developing countries, particularly in the semi-arid tropics and certain temperate regions (Timko et al., 2008). Cowpea seeds are excellent source of carbohydrate (50–60 %) and a crucial source of protein (18–35 %) (Stancheva et al., 2017; Addo-Quaye et al., 2011; Fatokun et al., 2018; Sharma and Lavanya, 2002). The seeds' crude protein content range from 23 % to 32 % (Diouf, 2011). Additionally, a significant number of minerals like vitamin A, iron, zinc, and calcium are present in cowpea (Quaye et al., 2009; Prinyawiwatkul et al., 1996). The production of the crop and the value chain provide smallholder farmers, particularly women, with a means of subsistence income (Odendo et al., 2011). Cowpea production is, however, severely constrained in Sub-Saharan Africa by persistent droughts that particularly harm the flowering and pod-filling stages (Owade al et., 2020). As a result, cowpea yields are extremely low in West Africa. Notably, extra early maturing genotypes that can escape drought periods prevent the effects of moisture stress limitation on protein or free amino acid formation and concentration in seeds. Agbicodo et al. (2009) indicated that drought conditions during the early stages of flowering and pod filling can cause yield losses of up to 80 %. Farmers strategically prefer to plant early maturing varieties at specific times so

* Corresponding author.
E-mail address: gamenorpe@yahoo.com (G. Amenorpe).

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that the flowering and pod-filling stages can avoid drought and pressure periods for pest invasion (Selvan et al., 2021; Ehlers and Hall, 1997). Farmers therefore, choose early maturing and high yielding crops in order to reduce the consequences of severe drought (Fatokun et al., 2012).

Unfortunately, because this species self-pollinates, the genetic diversity of cowpea is typically low. Gomes et al. (2020), Wamalwa et al. (2016), Kuruma et al. (2008) and Reis and Frederico (2000) who observed low levels of genetic variety based on morphological markers among cowpea accessions in Kenya further emphasized the assertion of the crop's narrow genetic variability. Until a spontaneous mutation takes place, the genetic makeup of self-pollinated plants like cowpea remains fixed throughout generations. Unssless a natural or spontaneous mutation occurs, the level of stability for homozygote lines can endure for generations. It is said that the frequency of spontaneous mutation is fairly low (Singh et al., 2013). The genetic diversity of cowpeas has barely increased due to the slow rate of spontaneous mutation. Therefore, it is crucial to use mutagenesis to increase genetic diversity in self-pollinated crops (Ronald, 2011; Singh et al., 2013). Faster external influences are typically used in artificial mutagenesis to hasten mutagenesis and the development of genetic variation. The selection of a mutagen for mutagenesis is largely influenced by previous achievements recorded for a crop species, as well as the cost and accessibility of mutagens (Bado et al., 2015). As high as 3, 218 mutant varieties of crops, including cowpea, have been developed and logged in the FAO and IAEA Mutant Varieties Database (MVD, 2012). For instance, Girija et al. (2013) observed cowpea seeds that had been exposed to gamma rays (20, 25, 30 kR) as well as EMS (20, 25, 30 mM) treatment. These researchers identified unique mutants with larger seeds and new seed coverings. Additionally, Gunasekaran et al. (1998) noted variance in various agronomic variables in M2 populations that had been subjected to gamma radiation or ethidium bromide mutagenization. According to the findings, gamma radiation causes mutations more effectively than ethidium bromide (Gaafar et al., 2016).

Furthermore, Horn et al. (2017) found four mutants with widespread adaption in Namibia at M7 and radiated four elite cowpea cultivars there. On two types of cowpea, Singh et al. (2006) conducted a thorough mutagenesis utilizing three chemical mutagens: ethyl methane sulfonate (EMS), methylmethane sulfonate (MMS), and sodium azide (SA). A wide range of macro mutations were seen in the offspring of both kinds in the M2 generation. The enhancement of cowpeas has been accomplished through the use of physical and chemical mutagenesis techniques, and the mutants that have been produced have met local farmers and consumers' expectations. Gamma radiation can be used to produce extra-early and early-maturing cowpea mutants because of its high penetration strength and energy levels (Amenorpe, 2010; Mba et al., 2010; Tshilenge-Lukanda et al., 2012; Nakatsuka and Koishi 2018; Ndinelao et al., 2018; Singh, 2007).

Induced mutation is a useful complementary approach to traditional plant breeding, especially when it is desired to enhance a few readily identifiable traits in a variety that is well-adapted (Navabi et al., 2016). In mutation breeding, novel traits are introduced through a modest modification to the basic genotype of the parental variety (Nakatsuka and Koishi 2018; Ndinelao et al., 2018). Increased genetic variability due to induced mutation has improved conventional breeding in many crops by widening the genetic base (Singh et al., 2006). The mutagenized population of the M1 generation may have subtle induced mutations as a result (Kolar et al., 2015). Therefore, in order to increase trait expression, M1 plants must be advanced at least to the M2 generation. According to Clement et al. (2015), Singh and Sharma (2016), and Reddy et al. (2013), it is preferable to begin screening traits at the M2 generation while the plant population is still small rather than in subsequent generations to forestall obscurity of judgement posed by a larger population. Early detection of helpful mutants demonstrates the efficacy of doses used and suggests a chance of finding additional useful mutants in subsequent generations (Amenorpe, 2010). The most popular, affordable, and effective method for phenotypically identifying mutations is visual screening (Shu et al., 2012). Therefore, the visual screening for quantitative traits, such as number of days to flowering, the number of pods per plant, seed yield per plant is preferably carried out in M2 generation. Omoigui et al. (2006) and Horn et al. (2016) studied the induced variability in cowpea and observed significant differences in the number of days to flowering, days to maturity, number of branches per plant, number of pods per plant, 100 seed weight, seed yield per plant in the M2 generation.

In general, cowpea varieties are categorized as extra early if they reach maturity 60 days or less after planting (DAP), early if they do so in 61–80 days, and late if they reach maturity in more than 80 DAP (Singh et al., 2007; Dugje et al., 2009; Hall et al., 2003; Egbe et al., 2010; Owusu, 2015). Twelve of the thirteen cowpea varieties that were released in Ghana are categorized as early maturing based on this earliness rating. The cultivars grown in Ghana have the following maturation times and yields: i. *Nhyira* (65–68 days; yield 2,460 kg/ha) (CSIR-CRI, 2006); ii. *Asuntem* (CSIR, 2005); iii. *Asentenap* (2,500 kg/ha) (CSIR-CRI, 1991); iv. *Zaayura* (64–67 days; 600 kg/ha) (CSIR-CRI, 2008); v. *Marfo-Tuya* (66–70; 600 kg/ha) (Monyo and Boukar, 2013); vi. *Apagbaala* (60 days; 600 kg/ha) (Monyo and Boukar, 2013); vii. *Padi-tuya* (64–67 days; 400 kg/ha) (Monyo and Boukar, 2013; CSIR-CRI, 2015); viii. *Songotra* (62–65 days; 600 kg/ha) (Monyo and Boukar, 2013); ix. *Bawutawuta* (69–75 days; 400 kg/ha) (Monyo and Boukar, 2013); x. *Hewale* (64–72 days); xi. *Videza* (68–77 days or 70 days based on average) (Adu-Dapaah and Addy, 2015) and xii. *Asomdwee* (65–72 days) (Owusu et al., 2018)). Only *Benpla* (55–60; 1,255 kg/ha) is an extra early variety (Quaye et al., 2011). The yield of the early varieties range from 400 kg/ha (*Padi-tuya* and *Bawutawuta*) to 2,500 kg/ha (*Nhyira* and *Asentenap*) and that for the extra early variety *Benpla* is estimated as 1,255 kg/ha. It is noteworthy that the extra early variety *Benpla* yields higher than most of the early varieties. This observation provides some indication that extra early varieties could be developed without significantly compromising on yield levels.

In order to circumvent the limitations imposed by periods of prolonged drought, the aim of this study was to develop cowpea genotypes that combine the traits of extra earliness and high seed yield by mutagenizing the parental variety *Videza* using gamma irradiation. Using *Videza* as parental control, selected M1 generations that showed extra earliness and high seed yield were advanced to M2 and then to M3. Cowpea varieties with extra early maturation and greater yields have enormous economic potential for revitalizing the cowpea agrobusiness since such improved varieties would allow the crop to avoid dry spells and irregular rainfall patterns brought on by climate change (Egbadzor et al., 2013).

2. Materials and methods

2.1. Research site, experimental design and agronomic practices

A field experiment was conducted on the research field of the Biotechnology and Nuclear Agriculture Research Institute (BNARI) of the Ghana Atomic Energy Commission (GAEC). The research area is situated in latitude 05 40′ and longitude 0 13′ West, 76 m above sea level. It is located in the coastal savannah zone and receives between 750 and 1000 mm of precipitation each year (Essel et al., 2016). According to Afram (2020), the major soil type is a well-drained sandy loam called Savannah Ochrosol (Ferric Acrisol, locally known as Haatso series), which is derived from quartzite schist. Irradiated seeds were planted the following day in the field at the BNARI Research Farm at aspacing of 80 cm × 40 cm. Each plot comprised five rows of six plants/row at a seeding rate of one seed per hill. The experiment was set up in a Randomized Complete Block design with three replications. Seeds and seedlings were watered twice per week to ensure adequate soil moisture for germination and

Figure 1. A. Number of days to flower. B. Number of days to maturity. Colours: Blue: induced plants; Yellow: Mean value of all induced plants; Green: un-induced plants.

growth. The biological effects of the gamma irradiation on the plants were studied following the protocols established at the Plant Breeding and Genetics Laboratory of the Joint FAO/IAEA (Spencer-Lopes et al., 2018; Essel et al., 2016; Afram, 2020).

2.2. Plant material and mass irradiation

A farmer-preferred variety of cowpea, *Videza* was used for the study. This was obtained from the best cowpea farmer in the Volta Region of Ghana, precisely in Avenorpedo (Akatsi-North District). This cowpea variety was first planted on the Research Farm of the Biotechnology and Nuclear Agriculture Research Institute (BNARI) between March 2018 to April 2018 and pods were harvested from the best performing single plant to ensure homogeneity of seeds. The harvested seed was multiplied from the best performing single selected plant, planted in the BNARI Research Farm, between July 2018 to September 2018, to obtain approximately 8,000 seeds. After radio-sensitivity test, mass irradiation was carried out as follows: Thousand eight hundred (1800) cowpea seeds were acutely irradiated in March 2019 at LD_{50} of 240.51Gy, at a dose rate of 300 Gy/h from Cobalt-60 (^{60}Co) source at the Radiation Technology Centre (RTC), Ghana Atomic Energy Commission (GAEC), Accra, Ghana. Zero (0Gy) dose served as control. Seeds with a moisture level of 12.8 %, 100 % germination, and in a dry, healthy, quiescent state were used.

2.3. Field establishment and selection at M1, M2 and M3 generations

On the field, the control seeds, irradiated seeds (M1), induced M2 and M3 seeds, were sown at a depth of 2 cm with spacings of 40 × 75 cm. Manual weed control was used. 30 induced plants were tagged at the M1, M2 generations, seeds harvested separately, and dried to yield seeds for the M3 generation. These plants flowered and reached maturity earlier than the parental control plant.

2.4. Preliminary evaluation of twelve genotypes for yield at M4 generation

The experiment was conducted during the minor season within the coastal savanna agro ecological zones. Nine induced plants (P5N05#10, P2N09#12, P5N07#14, P1N06#20, P1N06#9, P1N08#13, P6N10#19, P1N08#17, P4N14#7) selected on the bases of early maturity were evaluated with three commercial varieties (*Videza,* the control), *Hawale* and *Zamzam* under Randomized Complete Block Design (RCBD) with three replicates. The field had three blocks which were separated by 1 m alleys. Each replicate plots were also separated by 1 m alleys on each block. Each plots dimension was 6.11 m × 6.11 m. Each plot had ten rows by ten columns of cowpea plants. One seed was sown per hill at a spacing of 60 cm × 60 cm apart.

2.5. Statistical analyses

All induced plants from M1 to M3 populations were compared with their parental control for differences using excel and means determined for M3 populations. The preliminary yield trial was analysed for significant differences with GenStat Release 12.1 and significantmeans were separated by least significant difference values.

3. Results

3.1. Number of days to flowering and maturity at M3 generation

Figures 1A and B display the parental control (green bar) and M3 plants' maturation and days to 50 % flowering. The control plant required 45 days to flower and 70 days to mature, but the obtained mutant plants took 30–45 days and 48–60 days, respectively, to flower and mature. It took an average of 35 and 58 days for plants to flower or mature, respectively. On the basis of increased earliness and maturity compared to their overall mean (yellow

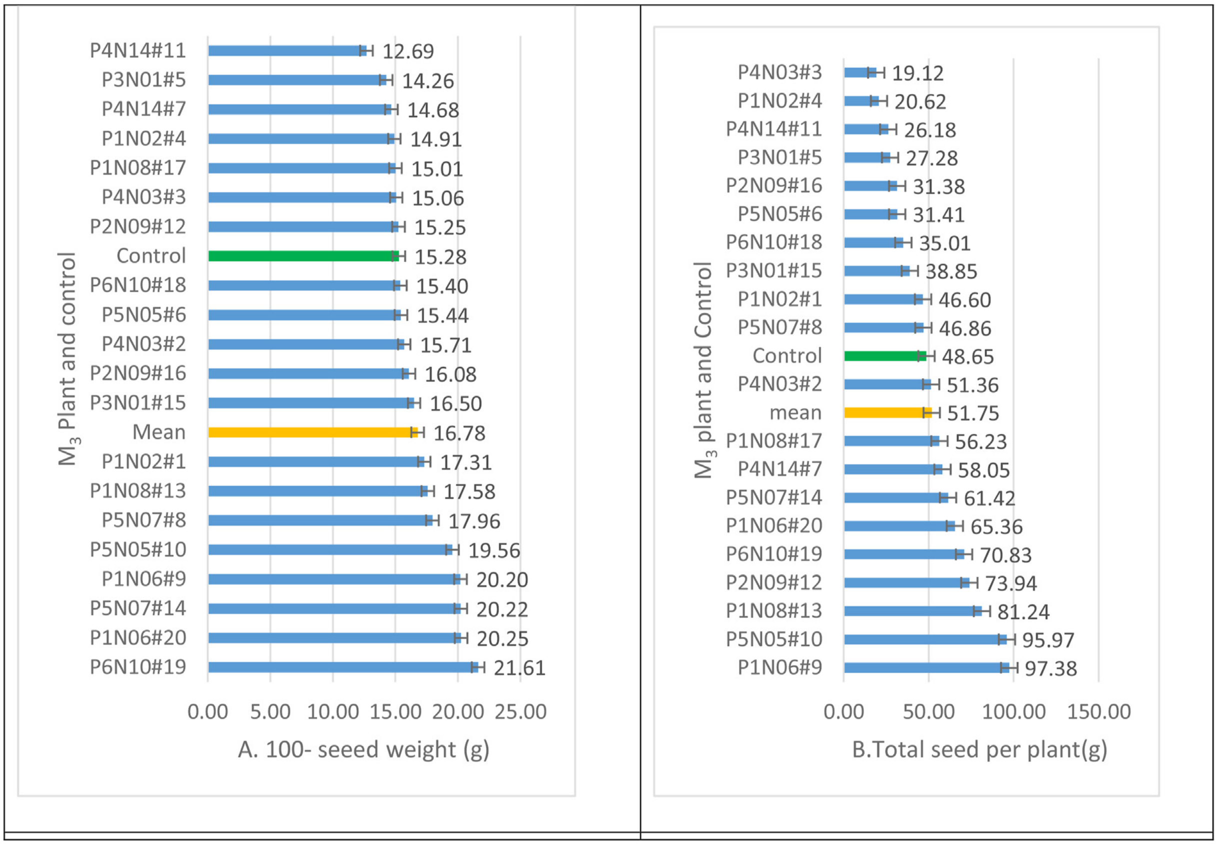

Figure 2. A. 100-seed weight. B. Total seeds per plant. Colours: Blue: induced plants; Yellow: Mean value of all induced plants; Green: un-induced plants.

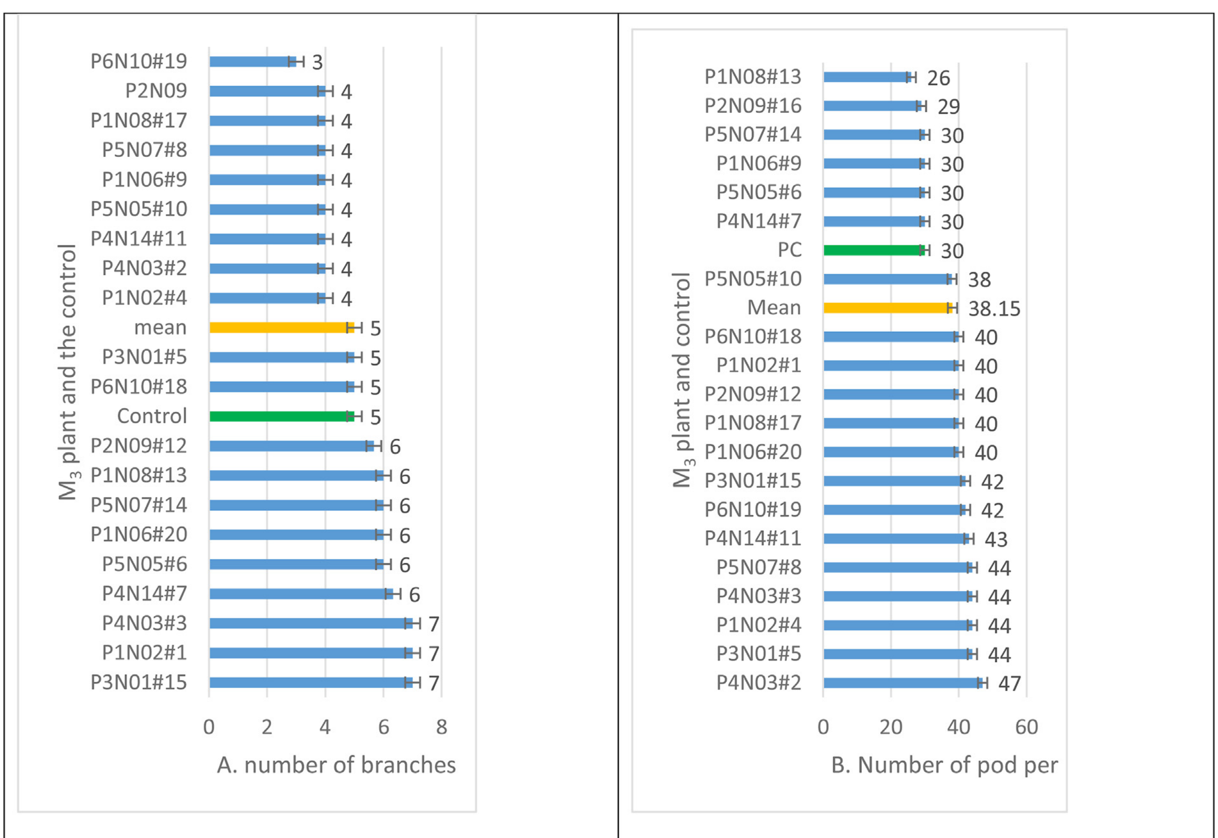

Figure 3. A. Number of branches per plant. B. Number of pods per plant. Colours: Blue: induced plants; Yellow: Mean value of all induced plants; Green: un-induced plants.

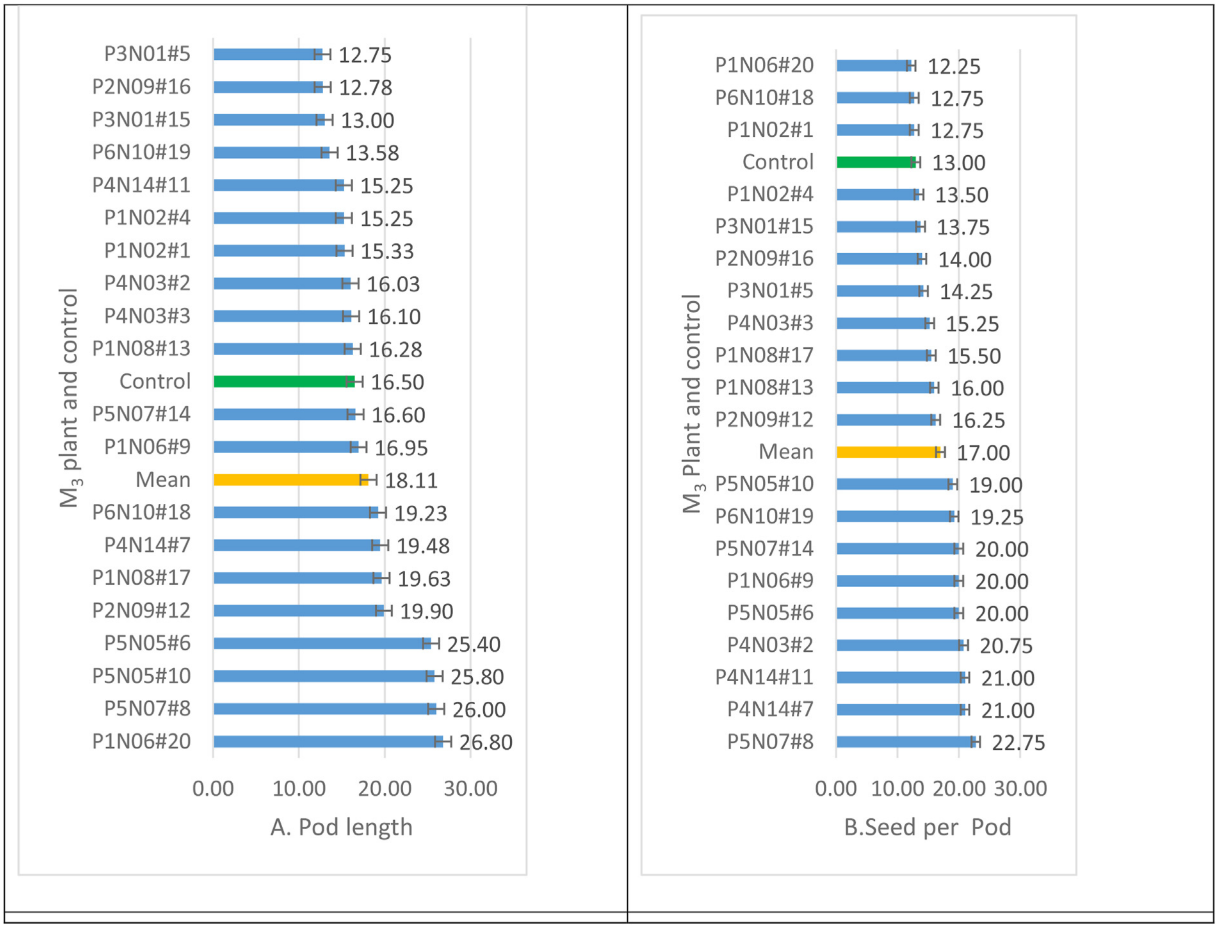

Figure 4. A. Pod length. B. Number of seed per pod. Colours: Blue: induced plants; Yellow: Mean value of all induced plants; Green: un-induced plants.

bar) and control (green bar), eight induced mutant plants were chosen (P1N06#20, P6N10#19, P6N10#18, P1N08#17, P2N09#16, P3N01#15, P5N07#14, P1N08#13, and P2N09#12).

3.2. A100-seed weight and total seeds per plant at M3 generation

The number of seeds per plant and the weight of 100 seeds are presented in Figures 2A and B. The control plant's 100-seed weight (green bar) was 15.25 g, and each plant had a total of 48.65 g of seeds. The overall weight of the seeds per plant varied from 19.12 to 97.38 g, while the weight per 100 seeds varied from 12.69 to 21.61 g. The average weight of 100 seeds per plant was 16.78 and 51.75 g. Ten induced plants significantly outweighed the mean value (yellow bar) in terms of 100-seed weight, and majority of these plants had significantly more total seeds per plant. On the basis of total seed production above the mean, nine plants (P1N06#9, P5N05#10, P1N08#13, P2N09#12, P6N10#19, P1N06#20, P5N07#14, P4N14#7, and P1N08#17) were chosen. The majority also had much higher 100-seed yields than the mean and control plants.

3.3. Number of branches and pods per plant at M3 generation

Figures 3A and B show the number of branches and pods per plant. The control plant (green bar) had 5 branches and 30 number of pods per plant. Number of branches and pods per plant ranged from 3 to 7 and 26 to 47, respectively. The mean (yellow bar) number of branches was 5 and 38.15 for pods per plant. Nine induced plants selected (P3N01#15, P1N02#1, P4N03#3, P4N14#7, P5N05#6, P1N06#20, P5N07#14, P1N08#13 and P2N09#12) on the basis of higher number of branches per plant than mean and control. Most of these plants also had higher number of pods per plant.

3.4. Pod length and number of seed per pod at M3 generation

Figures 4A and B illustrate the variation in pod length and the number of seeds per pod. The control plant (green bar) contained 13.0 seeds per pod and a pod length of 16.50 cm. The number of seeds per pod varied from 12.25 to 22.75, and the length of the pods ranged from 12.75 to 26.8 cm. The average pod length (yellow bar) was 18.11, and there were 17 seeds per pod. On the basis of having longer pods than the mean and control, eight induced plants (P1N06#20, P5N07#8, P5N05#10, P5N05#6, P2N09#12, P1N08#17, P4N14#7, and P6N10#18) were chosen. The majority of these plants also produced more seeds per pod.

3.5. Preliminary evaluation of twelve genotypes for yield at M4 generation

The yield per hectare was highly significant (F pr. < 0.001) (Figure 5). The CV %, mean and range values for yield per hectare were 38.23; 872.47 and 268.6–1235 respectively. Moreover there are significant difference between control and induced plants, as induced plants P5N05#10 (1235 kg/ha), P2N09#12 (1206 kg/ha), P5N07#14 (1185 kg/ha), P1N06#20 (1171 kg/ha), P1N06#9 (1051 kg/ha), P1N08#13 (1041 kg/ha) and P6N10#19 (999 kg/ha) had exceptional higher values than the control (517 kg/ha) and the rest.

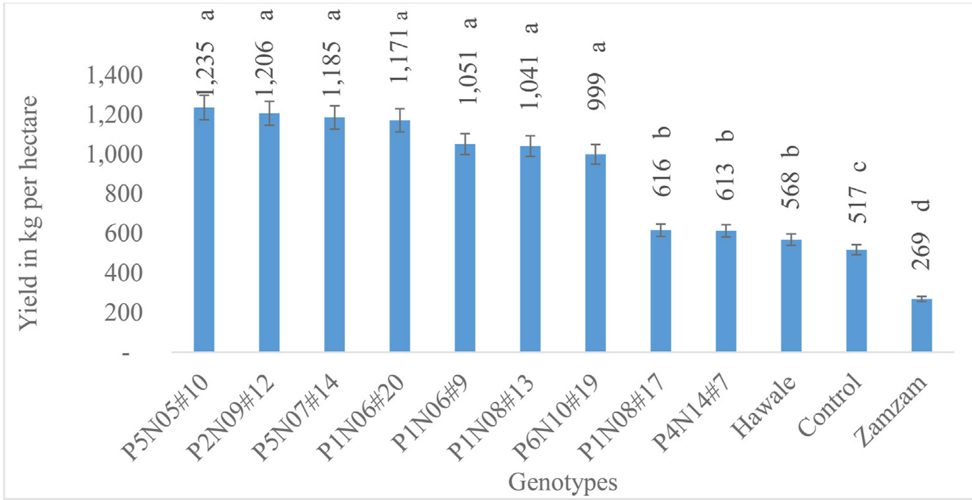

Figure 5. Mean field performance of genotypes.

4. Discussion

Negative environmental effects worsen climate-related yield instabilities in broad-leaved and grain legume crops more than they do in cereals (Dhankher and Foyer, 2018; Reckling et al., 2018). The likelihood of famine is predicted to increase due to rising temperatures, intensifying droughts, strong precipitation events, and insect and pathogen infestations that frequently accompany these factors (Long et al., 2015). Ghanaian cowpea producers consequently support vigorous research efforts to cut the number of days needed for flowering and maturation while increasing crop yields. The shorter gestation period varieties would enhance the sustainability of economic yields even with little rain before biotic and abiotic stress conditions set in to reduce yields as pertains in late maturing crops.

Although Cober and Curtis (2003) asserted that the activity of floral promoters and inhibitors mediate flowering time antagonistically and can even be sensed in unexpanded leaves or buds, photoperiod is the most significant environmental variable regulating time to flowering in cowpea. At least seven main genes, each of which is associated with an average flowering delay of up to six days, have been identified as controlling the time to flowering in cowpea (Boukar et al., 2019; Ishiyaku et al., 2005). *However,* Bernard (1971) discovered that the two main genes in soybeans that regulate flowering and maturity are independent, but the gene for lateness is connected to the colour of the pubescence. The late allele at each locus was only partially dominant in the majority of combinations, but gamma irradiation mutagenesis might change the order of the late allele at each locus, as well as the promoters and inhibitors that regulate flowering time, to cause extra early flowering in cowpea (Tripathi et al., 2020).

Extra early cowpea varieties mature in less than 60 days after planting, early varieties mature between 61 and 80 days after planting, and late varieties reach maturity in more than 80 days after planting (Singh et al., 2007; Dugje et al., 2009; Hall et al., 2003; Egbe et al., 2010; Owusu, 2015). The study showed that some induced plants have the ability to mature earlier than their mutagenized parents. For instance, genotype P4N14#7 matures extra-early at 54 days after planting (DAP) and flowers very early at 30 days after planting (DAP), but the control flowers 15 days later at 45 DAP and matures 16 days later at 70 DAP. The shorter flowering period and shorter days to maturity showed genetic diversity brought on by gamma radiation in the desired direction, allowing selection of mutants with extra-early maturation. Similarly, Horn et al. (2013) discovered significant genetic variation among induced cowpea genotypes at M5 based on flowering and maturity times. It was found that "Bira" mutant plants matured 62 days earlier than the control plant (74 days). Gamma rays-induced artificial genetic disruption of the parental genome may result in heritable insertions and or deletions of specific nucleotides or DNA sequences.

It was also observed that eight induced plants flowered extra earlier than the mean value of 33 DAP for induced plants. Most of these extra early mutant genotypes are earlier maturing than their parental control. For example P1N02#1 took 48 days to mature was followed by P4N03#3 (52 days), P3N01#5 (52 days), P5N05#6 (54 days), P4N14#7 (54 days), P5N07#8 (54 days), P5N05#10(54 days) and P4N14#11 (54 days), with mean value of 54.55 days which is extra earlier than the control of 70 days. The selection for extra flowering and early maturing plants was consistent with Laskar and Khan (2017) and Wu et al. (2005) who stated that most quantitative traits observed at the M2 generation are likely to recur in subsequent generations. Similar result was reported by Horn (2016) in cowpea, Tulmann and Alve (1997) in soyabeans and Karim et al. (2008) in chickpea. Therefore, the variability generated through gamma-radiation-induction was screened for useful extra early maturing cowpea genotypes such as P1N02#1 (which matures 48 days), followed by P4N03#3 (52 days), P3N01#5 (52 days), P5N05#6 (54 days), P4N14#7 (54 days), P5N07#8 (54 days), P5N05#10 (54 days) and P4N14#11 (54 days), which took 10–15 days to mature earlier than their parents.

By completing their life cycle within the brief rainy period before severe weather sets in, these extra early genotypes offer the opportunity to avoid seasonal drought and harmful heat stress in evaluated and released to farmers as varieties. Compared to late maturing varieties, extra early maturing cowpea mutant varieties may be better able to fend off insect and disease attacks. According to Singh et al. (2007) and Bozokalfa et al. (2017), many small-scale farmers deliberately favour shortened planting dates over longer durations in order to prevent complete crop failure. Bozokalfa et al. (2017) reported that farmers grow early maturing crop varieties because these varieties provide early harvest than the late maturing varieties. Farmers adopt early maturing varieties because such varieties are more reliable in the food security strategy of Sub-Saharan Africa. Increasing harsh unfavourable climate changes are rendering most late maturing varieties less useful due to significant decline in their efficient development and productivity. More extra early maturing varieties are, therefore, required to support efforts at mitigating the negative effects of climate change on achieving optimal level of food security (Egbe et al., 2010; Mligo, 1989). Extra early maturing cowpea varieties are ideal for intercropping with other crops because they offer less competition for growth resources than late maturing varieties (Ntare, 1990; Kamara et al., 2018). Besides, extra-early varieties open the possibility of successful single cropping in areas with short rainy seasons, double or triple cropping in areas with relatively longer rainfall. Extra early maturing cowpea varieties are amenable to relay cropping after millet, sorghum or maize, as well as intercropping with cereals and root and tubers (Egbe et al., 2010; Mligo, 1989).

For many farmers in the Sub-Saharan region, cowpea is a crucial cash crop. Therefore, an increase in agricultural output and seed size can significantly increase farmers' and their household's income. In this study, seed size was measured in terms of weight per 100 seeds, a statistic whose value constantly rises as seed size does (Herniter et al., 2019; Langyintuo et al., 2004). It was observed that total seed per plant had strong positive correlation (0.67) with a 100-seed weight. This implies that higher yielding cowpea genotypes could invariably produce higher 100 seed weight. The 100-seed weight in mutant genotypes ranged from 12.69 to 21.61 g. With a mean of 16.78 g, the mutant genotypes compared favourably with varieties cultivated in *Ghana*. *The* 100-seed weight of cowpea varieties *reported in Ghana range from 7.3 g to 40.1 g, with a mean of 17.4 g for larger seeds.* Moreover, these mutants being extra early in maturity, have advantage of being cultivated multiple times in the year than most existing varieties. However, compared to more advanced regions, yield performance of cowpea in Ghana is generally low. Herniter et al., 2019 indicated that cowpea varieties grown in for example the United States produce higher 100-seed weight of 20–25 g (Herniter et al., 2019).

This study also revealed that total seeds per plant ranged from 19.12 – 97.38 g. The control plant produced 15.28 g 100-seed weight and 16.78 g total seeds per plant at the M3 generation. It should be noted, however, that the observed seed size range for the induced mutant plants is higher than most of the previously reported weight of 12.2 g per 100-seeds in northern Ghana (Langyintuo et al., 2004). Some seed sizes were also larger than 14.4 g per 100-seeds in southern Ghana (Mishili et al., 2009). The observed increase in seed size could be due to mutagenic effect of the gamma rays applied. It was also observed from this *study that some* induced plants had higher 100-seed weight and total seed per plant than their mean and control at the M_3 stage. The mutant genotype P6N10#19 had higher 100-seed weight (21.60 g) and total seed per plant (97.38 g) than the mean and control. The increase in 100-seed weight and total seed per plant above the parent plant showed that variability has been induced in the desired direction and would offer the possibility for selecting high seed yielding mutants. The effectiveness of gamma radiation in causing increase in yield is extensively reported (Raina et al., 2020; Laskar and Khan, 2017; Badr et al., 2014; Wu et al., 2005). Badr et al. (2014) reported the potential of increasing growth and yield related parameters by gamma radiation. Chemical mutagens such as sodium azide have also been proven to increase genetic variability in cowpea genotypes with respect to control (Raina et al., 2020).

It was observed that total seed weight per plant has strong correlation (0.67) with 100-seed weight. Selection for higher total seed weight per plant therefore, included most genotypes (P5N21 (22.80), P10N23 (21.71), P10N28 (21.31), P10N29 (20.96), P6N10 (20.77), P5N04 (20.34), P6N09 (20.11), P5N11 (20.00), P6N22 (19.92), P1N03 (17.60) with higher 100-seed weight. Moreover, the possibility of recurrent selection of higher total seed weight per plant genotypes across generations confirm the notion that quantitative traits observed in the M2 generation are repeated in subsequent generations (Laskar and Khan, 2017; Wu et al., 2005). Similar result was reported by Horn (2016) in cowpea, Tulmann and Alve (1997) in soyabeans and Karim et al. (2008) in chickpea. Therefore in M3 generation, the recurrent selection of nine induced genotypes (P1N06#9 (97.38 g), P5N05#10 (95.97 g), P1N08#13 (81.24 g), P2N09#12 (73.94 g), P6N10#19 (70.83 g), P1N06#20 (65.36 g), P5N07#14 (61.42 g), P4N14#7 (58.05 g) and P1N08#17 (56.23 g) on the basis of total seed weight above their control and mean (51.75 g) are highly likely to be repeated in subsequent generations. The total seed weight per plant had strong correlation (0.67) with 100-seed weight. Therefore, selection for one trait might strongly lead to the selection for other. In this regard, on the basis of 100-seed weight six genotypes were selected among the top eight genotypes (P6N10#19 (21.61 g), P1N06#20 (20.25 g), P5N07#14 (20.22 g), P1N06#9 (20.20 g), P5N05#10 (19.56 g), P5N07#8 (17.96 g), P1N08#13 (17.58 g), P1N02#1 (17.31 g).

Plants with more branches were observed to have a greater number of pods per plant at a high positive correlation (0.66). This result is consistent with the significant positive correlation (0.988) between the number of branches and pods/plant obtained by Akram et al., 2016 and Horn et al., 2016). *The M3 genotypes (P4N03#2, P1N02#4, P3N01#5, P4N03#3, P5N07#8, P4N14#11, P3N01#15, P6N10#19, P1N02#1 and P1N06#20) which had more branches also had more number of pods per plant than the mean and control plants.*

An increase in the pod length was observed in some of the selected M_3 plants compared to the control. Pod length and the number of seed per pod showed positive relationship (0.79). *M3 plants with the longest pod length also produced highest number of seeds per pod. A similar result was reported by Raina and Khan (2020) and Pathak (1991). Gamma irradiation had been found to cause either an increase or decrease in pod length of* chickpea *(*Khan et al., 2005); soybean (Justin et al., 2012) and cowpea (Wani et al., 2018), The nine mutant genotypes (P5N07#8, P4N14#7, P4N14#11, P4N03#2, P5N05#6, P1N06#9, P5N07#14, P6N10#19, P5N05#10) produced higher number of seeds per pod than mean and control. These mutant genotypes are, therefore, good candidates for multi locational trials under different agro-ecological zones, for release as new varieties.

The major challenge for cowpea production in sub-Sahara Africa is poor seed yield. The continuous evaluation of mutant genotypes for high and stable yield varieties is the guaranteed approach to solving regional food security problems (Aliyu and Makinde, 2016). The yield per hectare obtained among the developed mutant genotypes was highly significant (F pr. < 0.001). The yield ranged from 268.6 to 129.7 kg/ha in all the genotypes. The significant difference between control and the mutants P5N05#10, P2N09#12, P5N07#14, P1N06#20, P1N06#9, P1N08#13 and P6N10#19 affirm the successful creation of mutants is from a single seed descend populations effected by gamma irradiation. This is because a single seed descend population of a self pollinated plant cannot produce significant differences in any trait under the same environmental condition unless induced by a mutagen. It is known that gamma irradiation influences growth hormones and cause increase in EBT (eriochrome black-T) production leading to an increase in plant vigour, flag leaf area and number of grain yield (Singh and Datta, 2010). The best performing genotype P5N05#10, exhibits extra early maturing and high yielding with an average of 38 pods per plant and 25.80 cm pod length compared to the parental control which produces 30 pods per plant and 15.5 cm pod length. P5N05#10 should therefore, be advanced via multi-locatonal trials and released as both extra early maturing and higher yielding variety.

5. Conclusion

From the early maturing, commercial control variety *Videza*, this work successfully developed extra early maturing, high seed production cowpea mutants. The reference variety *Videza* matures early, at 70 days after planting, however some induced mutant genotypes could mature even earlier, at 48 days after planting (DAP), as was seen for P1N02#1, 52 DAP for P4N03#3 and P3N01#5, and 54 DAP for P5N05#6, P4N14#7, P5N07#8, P5N05#10, and P4N14#11. The control variety yields as low as 48.65 g/plant but some induced mutant genotypes yield as high as 97.38 g/plant in P1N06#9, followed by P5N05#10 (95.97 g), P1N08#13 (81.24 g), P2N09#12 (73.94 g), P6N10#19 (70.83 g), P1N06#20 (65.36 g), P5N07#14 (62.42 g), P4N14#7 (58.23 g) and P1N08#17 (56.23 g). Genotype P5N05#10 takes only 54 DAP to produce 95.97g of seeds per plant whilst the control takes 70 days to produce 48.24 g of seeds per plant. P5N05#10 is, therefore, both early maturity and high yielding. P5N05#10 also produced an average of 38 pods per plant and 25.80 cm pod length compared to the parental control with 30 pods per plant and 15.5 cm pod length. After preliminary yield trial, it was observed that the mutant plants P5N05#10 (1235 kg/ha), P2N09#12 (1206 kg/ha), P5N07#14 (1185 kg/ha), P1N06#20 (1171 kg/ha), P1N06#9 (1051 kg/ha), P1N08#13 (1041 kg/ha) and P6N10#19 (999 kg/ha) had exceptional higher yields than the control (517 kg/ha) and two other commercial varieties, an indication that indeed a mutant has been created from a single seed descend populations by the gamma irradiation. It is recommended that the two best genotypes P5N05#10 and P2N09#12 could be advanced through multi-locational trials under different agro-ecological zones and released as both extra early maturing and high yielding cowpea variety.

Declarations

Author contribution statement

Innocent Kwaku Dorvlo, M. Phil degree: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Godwin Amenorpe, PhD; Harry Mensah Amoatey, Professor; Samuel Amiteye, PhD: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Jacob Teye Kutufam, First Degree: Performed the experiments.

Emmanuel Afutu, PhD; Elvis Asare-Bediako, Professor: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Alfred Anthony Darkwa, PhD: Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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