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Performance of 13 Bambara Groundnut (*Vigna subterranea* (L.) Verdc.) Landraces under 12 H and 14 H Photoperiod

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Abstract: The aim of this study was to identify bambara groundnut landraces which are less sensitive to photoperiod response. Variation in yields of bambara groundnut have been attributed among others to variation in photoperiod at different sowing dates. Thirteen bambara groundnut landraces were evaluated at 12 h: 12 h and 14 h: 10 h, light: darkness at the Department of Plant Agriculture, University of Guelph, Guelph, Ontario, Canada. Sunshine mix LA4 was put in 78-4 litre pots per growth chamber. Four gram of 20:20:20, N:P:K was added to each pot and thoroughly mixed with the soil. Each landrace was replicated in six pots. Growth chamber temperatures were maintained at 30 and 25°C, day:night at relative humidity of 60%. Growth chamber Photosynthetic Active Radiation (PAR) ranged between 250-300 (millimol) umol m^2 sec^{-1}. Days to seedling emergence were significantly lesser under 12 h than 14 h photoperiod ($p = 0.02$). Days to flowering were significantly higher under 14 h than 12 h photoperiod ($p<0.05$). Five landraces; Burkina, Mottled Cream, Zebra Coloured, Tan One and Tan Two (both from Tanzania) podded under both 12 h and 14 h photoperiod. All but two of the landraces podded under 12 h photoperiod. Leaf area, shoot dry weight and root dry weight per plant were all higher under 14 h than 12 h photoperiod. Genotypes that produced pods under 14 h photoperiod were observed to be early maturing relative to the others. Landraces were identified for cultivation in the lower and higher latitudes. Abstract of this article is presented in "IHC: Lisboa 2010, T09 Genetics and Breeding; T09.218".

Key words: Bambara groundnut, photoperiod, pod yield, Ghana, Tanzania, Burkina Faso, day length

INTRODUCTION

Bambara groundnut has a potential to contribute to food security in view of its ability to withstand drought. The crop has the capability of producing pods where temperatures are high and precipitation is low producing some yield where other leguminous plants will not survive (Doku and KariKari, 1971). Bambara groundnut seed produces a balanced meal containing a good combination of carbohydrates, protein and fats (Goli, 1997).

Evidence to suggest that bambara groundnut grown under long photoperiod produced more leaves than those grown under short photoperiod has been established (Brink, 1999). Under long photoperiod, increased leaf production resulted in a decrease in pod formation (Azam-Ali, 1998). Linneman (1993) observed that the onset of flowering, progress of flowering, onset of podding and progress in pod growth were all retarded by long daylength above 14 h. The effect on podding was however, greater than on flowering and that some plants fail to produce pods under photoperiods of 14 h and 16 h (Linneman, 1993). Flohr *et al.* (1990) observed that in groundnut cultivar Cv. NC AC 17090 flowering was not affected by photoperiod however, where daylength is greater than 15 h, the duration for peg and pod initiation and fruit maturity is increased. Hadley *et al.* (1983) however, reported that in cowpea, differential effects of photoperiod on the onset of flowering, pod production and maturity were not found.

Very little information however, exists on bambara groundnut landraces that are insensitive to photoperiod. This study was conducted to determine the performance of 13 bambara groundnut landraces to two photoperiod regimes; 12 h:12 h and 14 h:10 h, light:dark.

MATERIALS AND METHODS

Seed stock: Thirteen bambara groundnut landraces were used for this study. They are Tom, NAV 4, NAV Red, Mottled Red, Black Eye, Zebra Coloured, Mottled Cream,

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Brown with white eye, Black Seed, Red Eye all from Ghana; Burkina from Burkina Faso and Tan One and Tan two from Tanzania. The names of the landraces were given taking into consideration the colour and the source of the materials where local names did not exist.

Growth conditions and photoperiod treatments: Two growth chambers (Conviron USA) at the Department of Plant Agriculture University of Guelph, Canada were used for the study. Each growth chamber contained 78 four-litre pots arranged in a Completely Randomised Design (CRD) with each landrace replicated by six pots. The pots were filled with Sunshine Mix LA4 (55-65% Canadian Sphagnum peat moss, 35-45%, perlite, dolomitic limestone for pH adjustment and wetting agent). Nitrogen:Phosphorus:Potassium, 20:20:20 was applied at 4 g/pot at sowing. The fertilizer was mixed thoroughly with the soil, watered and left to settle till the next day.

Seeds were sown on the 11th of October, 2008 (Day 0) at two seeds per pot and thinned to one seedling per pot on emergence. Biological pest control was undertaken after crop establishment using *Amblyseius cucumeris* to control Western flower thrips and *Phytoseiulus persimillis* to control red spider mites. Growth chamber temperatures were kept at 30°C (day) and 25°C (night) and a Relative Humidity (RH) of 60%.

The growth chamber Photosynthetic Active Radiation (PAR) was measured with an Apogee, Model Basic Quantum Meter Electric Calibration (BQM-E) and ranged between 230-300 umol m^{-2} sec^{-1}. Light was supplied by incandescent 40 Watt bulbs, FO6T12 Sylvania cool white fluorescent Very High Output (VHO) 8 mm long and 2 small bulbs. The two photoperiod treatments were: 12 h:12 h (day: night) and 14 h:10 h (day: night). Pots were watered every three days for both photoperiod treatments. The positions of the pots were randomly shifted every three days to prevent any possible biasness due to the effect of the positions of the pots in the growth chamber and differences in light intensity within the chamber.

Data taken: Days to seedling emergence were recorded as the number of days seedlings in a pot emerged. Seedlings were considered to have emerged when the first true leaf had broken from the soil in the pot. Days to flowering was recorded as the number of days plants in a pot showed fully opened flower with visible corolla. Plants were harvested on the 15th of February, 2009. Pod numbers were determined by counting the number of pods harvested from a plant. Pod dry weight was taken as the oven-dried weight of pods harvested from a plant. Leaf area was measured by passing leaf samples through a leaf area meter (Li-3100, USA).

Root and shoot dry weights were determined as the oven dried weight of root and shoot harvested from a plant. Plant dry weight was obtained by placing them in an oven maintained at 80°C for 48 h after which the materials were weighed.

Morphological changes with respect to the two photoperiod treatments were also observed during the period of plant growth and development. No destructive analysis was done until the final plant harvest due to the few number of plants per landrace per growth chamber for this study.

Data analysis: Data were analysed for Variance (ANOVA) using the Statistical Analysis System (SAS, USA). Days to flowering, days to emergence, pod dry weight and root dry weight were log transformed before analysis. Significant differences among treatment means were determined at $p<0.05$.

RESULTS

Days to emergence: There was significant difference with respect to landrace ($p<0.0001$) and photoperiod ($p = 0.02$) in days to seedling emergence. No significant difference was observed with respect to photoperiod by landrace interaction (Fig. 1). Emergence occurred earlier under 12 h photoperiod in most of the landraces than under 14 h photoperiod. Burkina, Zebra coloured, Tan Two and Mottled Cream emerged relatively earlier than the other landraces in both photoperiod regimes.

Days to flowering: Significant differences were observed with respect to landraces ($p<0.0001$) and photoperiod ($p = 0.0002$) on days to flowering. No significant difference was however, observed on the landrace by photoperiod interaction. Plants sown under 12 h photoperiod flowered earlier than plants sown under 14 h photoperiod for all the landraces. Burkina, Mottled Cream and Zebra coloured flowered earlier under both 12 h and 14 h photoperiod. They all flowered below 40 Days after Sowing (DAS) under the two photoperiod regimes. Black Seed, Brown with white eye and Tom flowered late under both 12 and 14 h photoperiod (Fig. 2). They all flowered beyond 47 DAS under the two photoperiod regimes.

Number of pods: Significant differences were observed on pod numbers with respect to landraces ($p = 0.003$) and

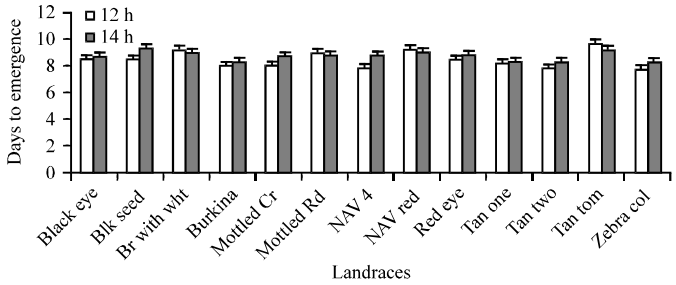

Fig. 1: Days to seedling emergence as affected by landraces and 12 and 14 h photoperiod. Bars indicate standard error of the mean

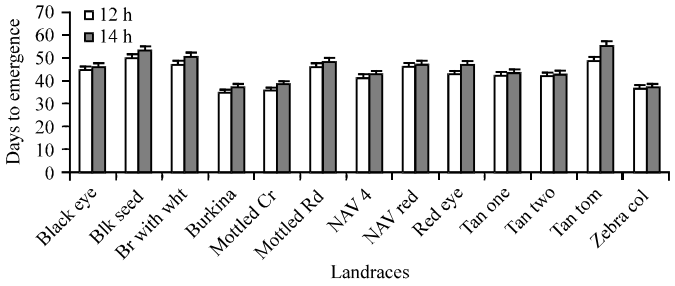

Fig. 2: Days to flowering as affected by landrace and 12 h and 14 h photoperiod. Bars indicate standard error of the mean

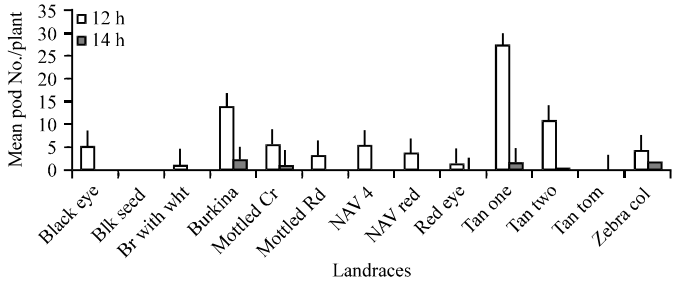

Fig. 3: Mean pod numbers/plant as affected by landraces and 12 and 14 h photoperiod. Bars indicate standard error of the mean

photoperiod ($p<0.0001$) and photoperiod and landrace interaction ($p = 0.003$). More pods were produced by the landraces under 12 h than under 14 h. All the landraces except Tom and Black Seed produced pods under 12 h photoperiod. Under 12 h, Tan One, one of the landraces from Tanzania produced the highest number of pods per plant (27 pods) followed by Burkina from Burkina Faso (13.75 pods) and Tan Two another landrace from Tanzania (10.67 pods). Under 14 h photoperiod, only 5 out of the 13 landraces produced some pods. Mean pods per plant produced by these landraces were; Burkina (2.25 pods), Mottled cream (1.00 pod), Tan One (1.75 pods), Tan Two (0.25 pod) and Zebra coloured (1.67 pods) (Fig. 3).

Pod dry weight: Pod dry weight was significantly different with respect to landrace ($p = 0.006$) and photoperiod ($p<0.001$). There was however, no significant difference with respect to interaction. Tan One produced the highest pod dry weight per plant (3.99 g) followed by Burkina (3.41 g) and Tan Two (2.18 g) all under 12 h photoperiod. Under 14 h photoperiod, Zebra coloured and Burkina produced mean pod dry weight of 0.38 g per plant followed by Tan One, Mottled Cream and Tan Two with 0.36 g, 0.23 and 0.05 g/plant, respectively (Fig. 4).

Shoot dry weight: Significant differences were observed in shoot dry weight with respect to landrace ($p<0.0001$) and photoperiod ($p<0.0001$). No significant difference was

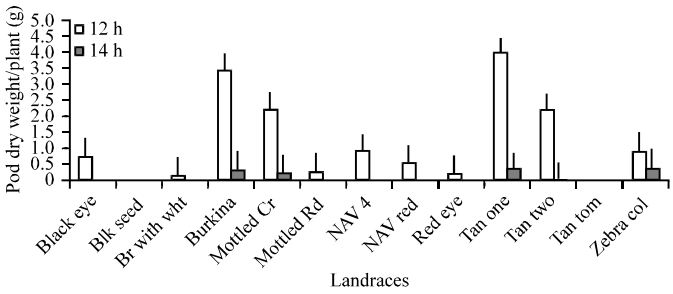

Fig. 4: Mean pod dry weight/plant as affected by landraces and 12 and 14 h photoperiod. Bars indicate standard error of the mean

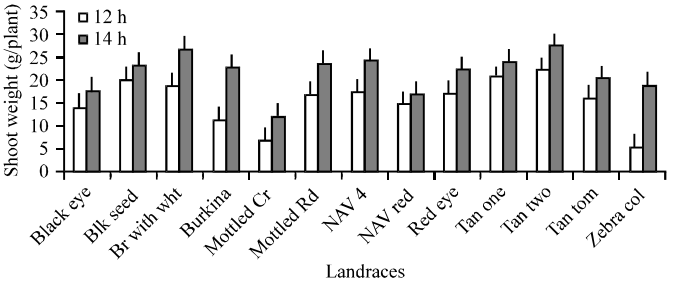

Fig. 5: Shoot dry weight/plant as affected by landraces and 12 and 14 h photoperiod. Bars indicate standard error of the mean

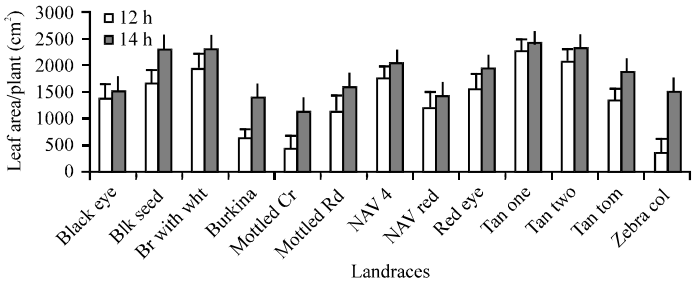

Fig. 6: Leaf area/plant as affected by landraces and 12 and 14 h photoperiod. Bars indicate standard error of the mean

observed with respect to landrace and photoperiod interaction. Shoot dry weight was higher under 14 h photoperiod than 12 h photoperiod. Tan Two under 14h photoperiod produced the highest mean shoot dry weight per plant (27.59 g) followed by Brown with white eye (26.85 g). Mottled Cream produced the least shoot dry weight under 14 h (11.71 g). Under 12 h photoperiod, Tan Two produced the highest shoot dry weight (22.23 g), followed by Black Seed (20.03 g) with Zebra coloured producing the least mean shoot dry weight per plant (4.86 g) (Fig. 5).

Leaf area per plant: Significant differences were observed in leaf area with respect to landrace ($p<0.0001$) photoperiod ($p<0.0001$). No significant interaction effect was observed. Leaf area was higher under 14 h than under 12 h. Tan One produced the highest mean leaf area per plant (2411.91 cm^2) under 14 h. Mottled Cream produced the least leaf area under 14 h (1113.00 cm^2). Under 12 h, Tan One produced the highest leaf area (2266.13 cm^2) with Zebra coloured producing the least leaf area (340.32 cm^2) (Fig. 6).

Root dry weight (g): Significant differences were observed in root dry weight with respect to landrace ($p = 0.004$) and photoperiod ($p = 0.02$). There was no interaction effect. Mean root dry weight was greater under 14 h photoperiod than under 12 h photoperiod.

Plant morphology: Bambara groundnut has been described as a trifoliate plant with three leaflets being borne on a petiole. It was interesting to note however, that Tan One from Tanzania had some of the plants producing three, four and five leaflets from the same plant (Fig. 7, 8). The crop has until recently been considered as an underutilized crop with little study done on it. It has not been bred for uniformity even though farmers have selected for characteristics which meet their taste like yield, taste, seed colour and seed size among others. Some of the landraces still maintained their primitive characteristics and it is possible this could have accounted for the Tanzanian landraces having the same plant with different leaflet numbers.

Canopy size within landraces was greater under 14 h photoperiod than under 12 h photoperiod for the same days after sowing. This was reflected on the higher leaf area within landraces under 14 h than under 12 h photoperiod (Fig. 9).

For the landraces that podded under both 12 h and 14 h photoperiods, more pods and less shoot development occurred under 12 h photoperiod whereas less pods and more shoot was formed under 14 h photoperiod (Fig. 10, 11).

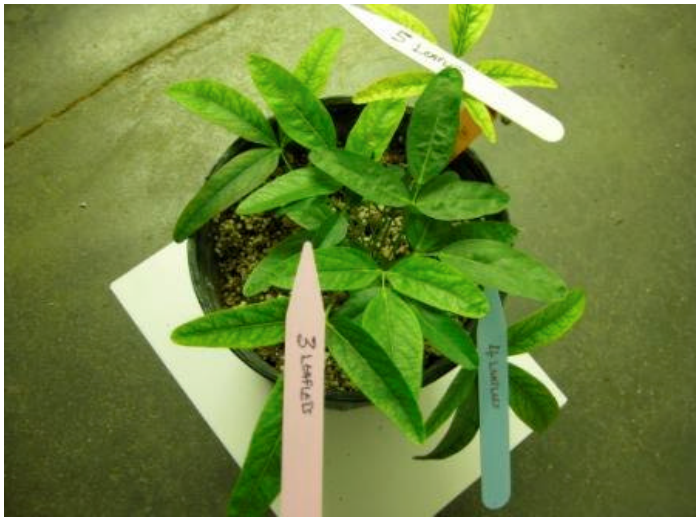

Fig. 7: Multiple (3, 4 and 5) leaflets on the same plant (Tan One from Tanzania) under 12 h , 108 days after sowing

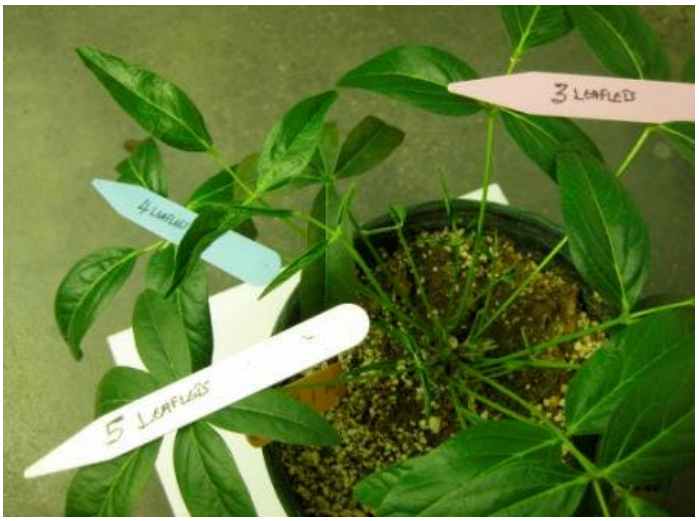

Fig. 8: Multiple (3, 4 and 5) leaflets on the same plant (Tan One from Tanzania) under 14 h, 108 days after sowing

Fig. 9: Canopy size under 12 h (L) and 14 h (R) photoperiod (Burkina 46 days after sowing)

Fig. 10: Pod development in Burkina under 12 h (Left) and 14 h (Right) photoperiod, 130 days after sowing

Fig. 11: Pod development in Mottled Cream under 12 h (Left) and 14 h (Right) photoperiod 130 days after sowing

DISCUSSION

Days to emergence: Emergence occurred earlier in most of the landraces under 12 h than under 14 h. This result is in agreement with findings from Chachalis and Reddy (2000) who reported that under fluctuating temperatures, 12 h photoperiod are required for maximum germination of *Campsis radicans*. This result shows the importance of date of planting on emergence and establishment of bambara groundnut especially in countries in the lower and higher latitudes where photoperiod effect has a practical implication in bambara groundnut cultivation. For early seedling emergence for quick and maximum canopy development to enhance optimum radiation capture and weed control, the role of agro-meteorologist in advising farmers on time of planting is crucial.

Days to flowering: Plants sown under 12 h photoperiod flowered earlier than plants sown under 14 h photoperiod for all the landraces. This result is in agreement with observations by Linneman (1993) who reported that the onset of flowering, progress of flowering, the onset of podding and pod development are all retarded by long photoperiod. Linneman (1993) observed that long photoperiod did not only delay the appearance of first flower but also continued to influence the production of subsequent flowers. Flohr *et al.* (1990) reported that flower, peg and pod production in groundnut are also affected by photoperiod, however, Hadley *et al.* (1983) however, observed that in cowpea differential effects of photoperiod on the onset of flowering, pod production and maturity were not found.

Number of pods and pod dry weight: Under 14 h photoperiod, only five out of the 13 landraces studied produced some pods. Pod development in bambara groundnut is fastest at daylength shorter than 12 h and slows down as day length increases (Harris and Azam-Ali, 1993). Working on common bean (*Phaseolus vulgaris* (L.), Wallace *et al.* (1993) and Wallace and Yan (1998) reported that long photoperiods inhibited the partitioning of dry matter to seeds and increased assimilate partitioning to vegetative organs. Harris *et al.* (1988) also observed that under short daylength, more assimilates were partitioned to pods in peanut. Even though Burkina produced more pods (2.25 pods) under 14 h than Zebra (1.67 pods) they both registered the same pod dry weight. This was because Zebra produced more mature pods even though fewer under 14 h. This could be due to the fact that Zebra may be an earlier maturing landrace than Burkina. Berchie *et al.* (2010) evaluating three early maturing bambara groundnut landraces observed that Zebra coloured was identified to be earliest maturing followed by Mottled cream and Burkina. Similarly, Tan One produced more pods under 12 h (27 pods) relative to Burkina (13 pods), mean pod dry weight for the two landraces were not significantly different. This could be due to Burkina having a higher 100 seed weight than Tan One which has smaller seed size. It is also possible being an earlier maturing landrace Burkina might have produced more mature pods with higher dry matter content than Tan One at the time of harvest.

It is interesting to note that landraces that emerged earliest and flowered earliest were those that produced pods under 14 h. These landraces may possibly be the early maturing genotypes. Edamame (pronounced "eh-dah-MAH-may") is a traditional Japanese vegetable also called "vegetable soybean" and "sweet bean" a nutritious and tasty vegetable or snack food with a sweet nutty flavor (Miles *et al*., 2000). Miles *et al.* (2000) reported that all edamame except the earliest maturing varieties are photoperiod sensitive and for cultivation in the high latitudes under long summer days, early maturing varieties which are less sensitive to photoperiod must be cultivated. Traditional pigeon pea cultivars are highly sensitive to photoperiod and take from 175-280 days to mature (Mcpherson *et al*., 1985). However, Singh *et al.* (1997) reported that early maturing pigeon pea varieties developed by the International Crop Research Institute for the Semi Arid Tropics (ICRISAT) are relatively photoperiod insensitive and mature in 125 to 140 days. Long photoperiod has been documented to delay pod formation or prevent pod formation. It is possible the early maturing bambara groundnut landraces could make up for the delay in pod development caused by using full season landraces.

Not much study has been done to identify early maturing bambara groundnut landraces. The present studies have identified five landraces (Burkina, Zebra coloured, Tan One, Tan Two and Mottled cream) that are potentially early maturing and which are also less sensitive to photoperiod. Practically this result enables bambara groundnut farmers to obtain materials which can enable them to harvest some pods even when sowing is delayed due to the onset of rains in photosensitive agro-ecological zones in Africa, Asia and Latin America.

Shoot dry weight: Azam-Ali (1998) reported that the continuous leaf production of bambara groundnut landraces under longer daylength is associated with a corresponding decline in the fraction of dry matter allocated to pod structures. This observation was made in the present study where under 14 h photoperiod plants produced more vegetative materials hence more shoot dry

weight than under 12 h where plants relatively produced more pods and less shoot dry weight.

Leaf area: Working on photoperiod responses of extra early short duration pigeon pea lines developed at different latitudes, Chauhan *et al.* (2002) observed an increase in total dry matter in all lines which was attributed to increase in both number of leaves, individual leaf area and consequently increased leaf area duration. In the present studies, leaf area significantly increased under 14 h photoperiod relative to the 12 h photoperiod. Increased leaf area duration under 14 h photoperiod was observed. It is possible with relatively more assimilate partitioned to pods under 12 h photoperiod, leaf senescence was higher under 12 h photoperiod with the formation of fewer new leaves even though the crop is indeterminate. This however, was not the case of the 14 h photoperiod where assimilates were directed into leaf growth and development with increased leaf area. At harvest time leaf senescence by visual observation was much more prominent under 12 h than under 14 h photoperiod.

CONCLUSION

Controlled environment studies at the University of Guelph confirmed the findings that long photoperiod favoured vegetative growth at the expense of pod development in bambara groundnut. Five landraces were identified to be relatively less sensitive to photoperiod. These are; Burkina, Zebra coloured, Mottled cream, Tan One and Tan Two. All these landraces were identified to be relatively early maturing. Tan One produced some plants which produced three, four and five leaflets on different petioles of the same plant.

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REFERENCES

Azam-Ali, S.N., 1998. Bambara groundnut yield/ecology: Evaluating the potential for bambara groundnut as a food crop in semi-arid Africa. An approach for assessing the yield potential and ecological requirements of an underutilised crop. Summary Report of European Commission supported STD-3 Projects, Published by CTA., pp: 133-136.

Berchie, J.N., J. Sarkodie-Addo, H. Adu-Dapaah, A. Agyemang, S. Addy, E. Asare and J. Donkor, 2010. Yield evaluation of three early maturing bambara groundnut (*Vigna subterranea* L. Verdc) landraces at the CSIR-Crops Research Institute, Fumesua-Kumasi, Ghana. J. Agron., 9: 175-179.

Brink, M., 1999. Development, growth and dry matter partitioning in bambara groundnut (*Vigna subterranea*) as influenced by photoperiod and shading. J. Agric. Sci. Cambridge, 133: 159-166.

Chachalis, D. and K.N. Reddy, 2000. Factors affecting *Campsis radicans* seed germination and seedling emergence. Weed Sci., 48: 212-216.

Chauhan, Y.S., C. Johanssen, M. Jung-Kyung, L. Yeong-Ho and L. Suk-Ha, 2002. Photoperiod responses of extra-short duration pigeon pea lines developed at different latitudes. Crop Sci., 42: 1139-1146.

Doku, E.V. and K.S. KariKari, 1971. Bambara groundnut. Econ. Bot., 25: 225-262.

Flohr, M.L., J.H. Williams and F. Lenz, 1990. The effect of photoperiod on the reproductive development of a photoperiod sensitive groundnut (*Arachis hypogaea* L.) Cv. NC Ac 17090. Exp. Agric., 26: 397-406.

Goli, A.E., 1997. Introduction. In: Bambara Groundnut *Vigna Subterranea* (L.) Verdc: Proceedings of the Workshop on Conservation and Improvement of Bambara Groundnut (*Vigna Subterranea* (L.) Verdc.) : 14-16 November 1995, Harare, Zimbabwe, Heller, J., F. Begemann and J. Mushonga (Eds.). Institute of Plant Genetics and Crop Plant Research, Gaterleben, pp: 3-10.

Hadley, P., E.H. Roberts, R.J. Summerfield and F.R. Minchin, 1983. A quantitative model of reproductive development in cowpea (*Vigna unguiculata* L. Walp) in relation to photoperiod and temperature and implications for screening germplasm. Ann. Bot., 51: 531-543.

Harris, D. and S.N. Azam-Ali, 1993. Implications of daylength sensitivity in bambara groundnut (*Vigna subterranea*) for production in Botswana. J. Agric. Sci., 120: 75-78.

Harris, D., R.B. Matthews, R.C. Nageswara Rao and J.H. Williams, 1988. The physiological basis for yield differences between four genotypes of peanut (*Arachis hypogaea* L.) in response to drought, III. Developmental processes. Exp. Agric., 24: 215-226.

Linneman, A.R., 1993. Phenological development in Bambara groundnut (Vigna unguiculata) at constant exposure to photoperiods of 10-16h. Ann. Bot., 71: 445-452.

McPherson, H.G., I.J. Warrington and H.L. Turnbull, 1985. The effect of temperature and daylength on the rate of development in pigeon pea. Ann. Bot., 56: 597-611.

Miles, C.A., T.A. Lumpkin and L. Zenz, 2000. Edamame a Pacific Northwest Extension. Washington State University Publication, Washington, pp: 8.

Singh, B.B., O.L. Chambliss and B. Sharma, 1997. Recent Advances in Cowpea Breeding. In: Advances in Cowpea Research, Singh, B.B., D.R. Mohan Raj, K.E. Dashiell and L.E.N. Jakai (Eds.). Co-Publication of IITA, Ibadan, Nigeria and JIRCAS, Sayce Publishing, Devon, UK., pp: 114-128.

Wallace, D.H. and W. Yan, 1998. Plant Breeding and whole System Crop Physiology. CAB International Publisher, Wallingford, Oxon, UK.

Wallace, D.H., K.S. Yourstone, P.N. Masaya and R.W. Zobel, 1993. Photoperiod gene control over partitioning between reproductive vegetative growth. Theor. Appl. Genet., 86: 6-16.