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Original Research Article

ASSESSMENT OF SPIDER PLANT (*Cleome gynandra* L.) GERMPLASM FOR AGRONOMIC TRAITS IN VEGETABLE AND SEED PRODUCTION :- A GREEN HOUSE STUDY

ABSTRACT

Aims: Spider plant (*Cleome gynandra* L.) is one of the most important traditional vegetables in Kenya, albeit underutilized. Concurrently, scanty information is available on its potential for vegetable and seed production. The objective of this study was therefore to evaluate spider plant germplasm for agronomic traits pertinent to seed and vegetable production

Study design: A complete randomized design (CRD) with three replicates was used.

Place and Duration of Study: Two greenhouse experiments were conducted at Upper Kabete Field Station of the University of Nairobi, Kenya, for a period of 180 days (March-August, 2014).

Methodology: Twenty-five genotypes obtained from the Gene bank of Kenya and farmers' fields were grown in 10 kg pots filled with a mixture of soil and cow manure at ratio of 1:2. Three seeds of each genotype were planted per pot and evaluated for days to seedling emergence, germination percent, leaf formation, days to flowering, days to pod formation, number of pods per plant, number of seeds per pod and weight of 100-seeds.

Results: Seedling emergence, leaf formation, days to flowering, days to pod formation, number of pods per plant, number of seeds per pod and 100-seed weight varied significantly ($P=0.05$) between genotypes. Nineteen out of 25 genotypes emerged within 5 to 7 days, time to flowering ranged between 30 days in GBK-045494, and 42 days in GBK-040449, GBK-032229 and GBK-032134. Eight genotypes produced between 11 and 13 leaves per plant within six weeks. All the genotypes had a low (<50%) germination percentage.

Conclusion: GBK-040449, GBK-027212, GBK-032210 and GBK-032340 with; 4-7 days to emergence, ≥ 11 leaves per plant and ≥ 35 days to flowering are desirable for vegetable production, whereas, GBK-040449, GBK-045494 and SN 1 with ≥ 40 Days to pod formation, 6-9 pods per plant; ≥ 100 seeds per pod and 0.14-0.16g per 100-seeds are recommended for seed production. GBK 040449 was found to have traits suitable for both vegetable and seed production.

13 1. INTRODUCTION

14 Biodiversity holds an enormous potential of transforming agricultural and industrial systems
15 for economic growth and poverty reduction (1). The unique species of plants and animals as
16 well as ecosystems constitute the natural wealth of African continent (2). Unfortunately, this
17 diversity is underutilized and has paved way for genetic erosion. For sustainable use and
18 conservation of biodiversity, African countries need to harness and apply science and
19 technology (<http://www.nepadst.org/platforms/biodiv.shtml>). Out of thousands of wild and
20 domesticated edible plant species that are documented globally (3, 4), about 150 are traded
21 internationally, while only 15 of them constitute the main sources of human food (5). Given
22 the threats from climate change, diseases and pests, the narrowing range of domesticated
23 species poses a risk to food security (6). Domestication and cultivation of wild edible plants
24 is, therefore, essential in broadening the food base in developing countries. This will lead to
25 diversification, which will ensure intake of micronutrients and a dietary balance (6).

26 Little is known about the extent and structure of genetic variation, and the potential for crop
27 improvement through domestication, selection and/or breeding of most indigenous
28 vegetables, such as spider plant (*Cleome gynandra* L.). A number of factors pose as a
29 hindrance to cultivation and subsequent utilization of spider plant. For instance, its status as
30 a wild and weedy or volunteer crop creates the misconception that the crop is a vegetable
31 for the poor (7). Its relatively low yield is also an impediment to commercial production while
32 its bitter taste adversely affects its palatability, especially among children and the youth. This
33 might have contributed to the general neglect, research wise, by the National Agricultural
34 Research institutes (6, 7). The few accessions held in the national gene bank of Kenya were
35 collected during expeditions to conserve important species found in the country. However,
36 they have not yet been formally characterized or used in research programs (8).
37 Consequently, its optimum production potential and requirements, adaptation to specific
38 ecological zones and systematic comparison with other leafy vegetables, to establish its
39 comparative advantages remains scanty.

40 Although spider plant accessions have been conserved at the gene bank in Kenya,
41 information that could guide growers and scientists during selection for superior traits in
42 vegetable and seed production is inadequate. The objective of the current study was
43 therefore to assess spider plant genotypes for agronomic traits desirable in seed and
44 vegetable production

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46 2. MATERIAL AND METHODS

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48 2.1 Genotypes selection and assessment

49 Twenty-five (25) genotypes were assessed for agronomic traits and seed production under
50 greenhouse conditions, at the University of Nairobi - Kabete experimental field station, for a
51 period of 180 days (two plantings). The germplasm included 23 genotypes (GBK-043595,
52 GBK-040458, GBK-040455, GBK-040449, GBK-045431, GBK-045446, GBK-045426, GBK-
53 045436, GBK-045497, GBK-045494, GBK-045456, GBK-027212, GBK-032229, GBK-
54 032253, GBK-043266, GBK-032302, GBK-032210, GBK-031896, GBK-031841, GBK-
55 032134, GBK-028554, GBK-031850, and GBK-032340), which were obtained from the gene
56 bank of Kenya; and KS1 and SN1 obtained from farmers in Kisii and South Nyanza regions
57 of western Kenya, respectively. Saga, a commercial type, was included as a check.

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61 **2.2 Experimental Procedure**

62 The genotypes were grown in 10 kg pots filled with a mixture of soil (dark reddish-brown to
63 dark brown, friable clay) and cow manure mixed in the ratio of 1:2. The soil (deep red humic
64 nitisols according to Kenya Soil Survey (9) classification) and cow manure were obtained
65 from the University of Nairobi, Kabete experimental field. Three seeds of each genotype
66 were planted per pot. The pots were arranged in a completely randomized design (CRD)
67 with three replicates. The pots were watered / irrigated three times per week until plant
68 maturity.

69 **2.3 Data collection and Analysis**

70 Data on desirable traits was scored based on; days to seedling emergence, germination
71 percent, leaf formation, days to flowering (vegetable production traits), days to pod
72 formation, pods per plant, number of seeds per pod and weight of 100 seeds (seed
73 production traits). Day to flowering (50% flowering) was taken when 50% of the plants had
74 flowered while days to pod formation was recorded when 50% of the plants had formed
75 pods. For the determination of pods per plant, ten plants were randomly selected per
76 genotype in the three replicates and the number of pods in each was counted and an
77 average number of pods of three replicates was also calculated. Similarly for the
78 determination of number of seeds per pod, ten plants were randomly selected in each
79 genotypes for each of the replicates and 5 pods were pick at random from each of the plants
80 and the seeds contained in each pod was counted and recorded and eventually an average
81 per plant calculated. The 100 seed weight was determined by counting 100 seeds of each of
82 the genotypes replicated three times and weighed using a sensitive weighing scale and an
83 average for the 100 seeds calculated.

84 The data collected were subjected to analysis of variance using Genstat statistical package
85 (10) and means were compared using Fisher's protected LSD at $P=0.05$

86

87 **3. RESULTS AND DISCUSSION**

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89 **3.1 Days to Seedling Emergence**

90 Genotypes differed significantly ($P=0.05$) in the number of days taken from planting to
91 seedling emergence (Table 1). The days to emergence ranged between 4 days for genotype
92 GBK-031850 and 10 days for genotypes GBK-045431 and GBK-031896. Nineteen out of the
93 25 genotypes evaluated took 5 days to 7 days to emerge. This was not significantly ($P=0.05$)
94 different from the commercial variety-Saga that took 6 days to emerge. Genotypes GBK
95 043595, GBK 045431, GBK 032253, GBK 032302 and GBK 031896 took longer (8-10 days)
96 to emerge compared to Saga.

97 Temperature and light have been shown to have a significant influence on germination of
98 spider plant, where best conditions for seed germination are 20-30°C in darkness. Besides,
99 proper processing of seed determines the quality of the seed for example sun-drying of
100 spider plant seeds improve the mean germination time, seedling vigour and overall
101 germination percent compared with shade dried seeds (11). During the experimental period,
102 air temperature ranged between 15.9°C and 18.5°C. In addition, majority of the genotypes
103 used were obtained from the genebank of Kenya having been stored at -20°C for a long
104 period and, therefore, there is need for regeneration of germplasm stored in the genebank

periodically. Two genotypes (KS1 and SN1) were obtained from the farmers and one of the genotypes was a commercial variety (Saga). It is possible that the processing of seed for these genotypes was not done according to the recommendations (Mr. Katimbwa-Agricultural extension officer, Kisii, personal comm.).

Table 1: Genetic variability in 26 spider plant genotypes in relation to number of days to emergence, germination percentage, and days to flowering evaluated under greenhouse conditions

Genotype	Days to emergence	Germination (%)	Days to flowering
GBK-043595	8dc	27.8	41f
GBK-040458	6bc	33.3	36bcdef
GBK-040455	6bc	27.8	37bcdef
GBK-040449	6bc	44.4	42f
GBK-045431	10e	38.9	33abc
GBK-045446	7c	33.3	32ab
GBK-045426	6bc	38.9	37bcdef
GBK-045436	6bc	50.0	31a
GBK-045497	7c	38.9	34abcd
GBK-045494	7c	33.3	30a
GBK-045456	7c	33.3	35abcd
GBK-027212	6bc	44.4	38cdef
GBK-032229	7c	38.9	42f
GBK-032253	8dc	50.0	35abcd
GBK-043266	6bc	33.3	41f
GBK-032302	9de	33.3	41f
GBK-032210	6bc	44.4	40def
GBK-031896	10e	27.8	40def
GBK-031841	5ab	38.9	32ab
GBK-032134	6bc	16.7	42f
GBK-028554	5ab	38.9	38cdef
GBK-031850	4a	44.4	33abc
GBK-032340	6bc	44.4	39def
Commercial variety	6bc	38.9	35bcde
KS 1(Kisii)	7c	27.8	41f
SN 1 (South Nyanza)	6bc	27.8	36bcdef
LSD	2.1**	22.05ns	6.138**

**= Significant (P=.05), ns=Not significant. Figures followed by the same letters along a column are not significantly different (P=.05)

Spider plant seeds are negatively photosensitive and the effects of photo inhibition increase at temperatures lower than 20°C and germination is also influenced by physiological maturity of the seeds (12). The consequence of genotypes that take a long time to germinate may result in a poor final plant stand and hence reveal low leaf yields per unit area. The longer seeds are in the soil before germination or the slower the germination, the greater the chances for soil diseases and insects to attack the seeds (13).

3.2 Germination Percent (Stand Count)

There were no significant differences among genotypes for germination percent (Table 1). The germination percent ranged from 16.7% in GBK-032134 to 50% in GBK-032253. Genotypes GBK 040449, GBK-027212, GBK-032210, GBK-031850 and GBK 032340 had a germination of 44.4%, and though not statistically significant, different than that of Saga (38.9%). In addition, this percent was slightly higher than that of the genotypes (KS1 and SN1) obtained from farmers' fields, which was 27.8%. Genotypes GBK-032253, GBK 040449, GBK-027212, GBK-032210, GBK-031850 and GBK032340 that had germination of 40% - 50 % that was better than Saga (38%) and the farmers genotypes (27%) would give a higher plant population and hence higher yields as compared to genotypes currently being used by the farmers.

The number of plants established from a given weight of seed depends on size of seeds and percent of those seeds that are viable and can grow into established plants (14). A high seed germination percent is a prerequisite for successful commercial vegetable production (15).

3.3 Days to Flowering

The number of days to flowering varied significantly (P=.05) among genotypes (Table 1). The shortest duration to flowering was 30 days for GBK-045494, whereas the longest period to flowering was 42 days for GBK-040449, GBK-032229 and GBK-032134. Saga took 35 days from planting to flowering, which was shorter than the genotypes being grown by the farmers (KS 1SN 1) that took 41 and 36 days to flowering, respectively. The other genotypes that were slow in flowering as compared to Saga were GBK-045426 (37 days), GBK-027212 (38 days), GBK-028554 (38 days), GBK-032340 (39 days), GBK-031896 (40 days) and GBK-032210 (40 days) (Table 1).

Late flowering genotypes are the most preferred by farmers of leafy vegetables since the start of flowering marks the end of the vegetative stage and the reproductive stage sets in with reduced leaf production (16, 17). The main obstacle to spider plant production as a vegetable is that most of the genotypes currently being used by the farmers tend to flower very early and hence low leaf yields. Genotypes GBK-040449, GBK-032229 and GBK-032134 took seven days longer to flower when compared with the commercial variety. A difference of 7 days is significant in terms of leaf yield and income for a vegetable farmer harvesting the leaves twice a week. Therefore the genotypes that take more than 35 days from planting to flowering will represent good candidates for improvement for vegetable purposes.

3.4 Leaf formation

157 The leaf formation varied significantly ($P<0.05$) between genotypes (Figure 1). Eight out of
158 the 22 genotypes (GBK 045446, GBK 045426, GBK 045456, GBK 032340, GBK 032302,
159 GBK-032210, GBK-027212 and GBK 040449) evaluated accumulated leaf number of
160 between 11 and 13 in six weeks.

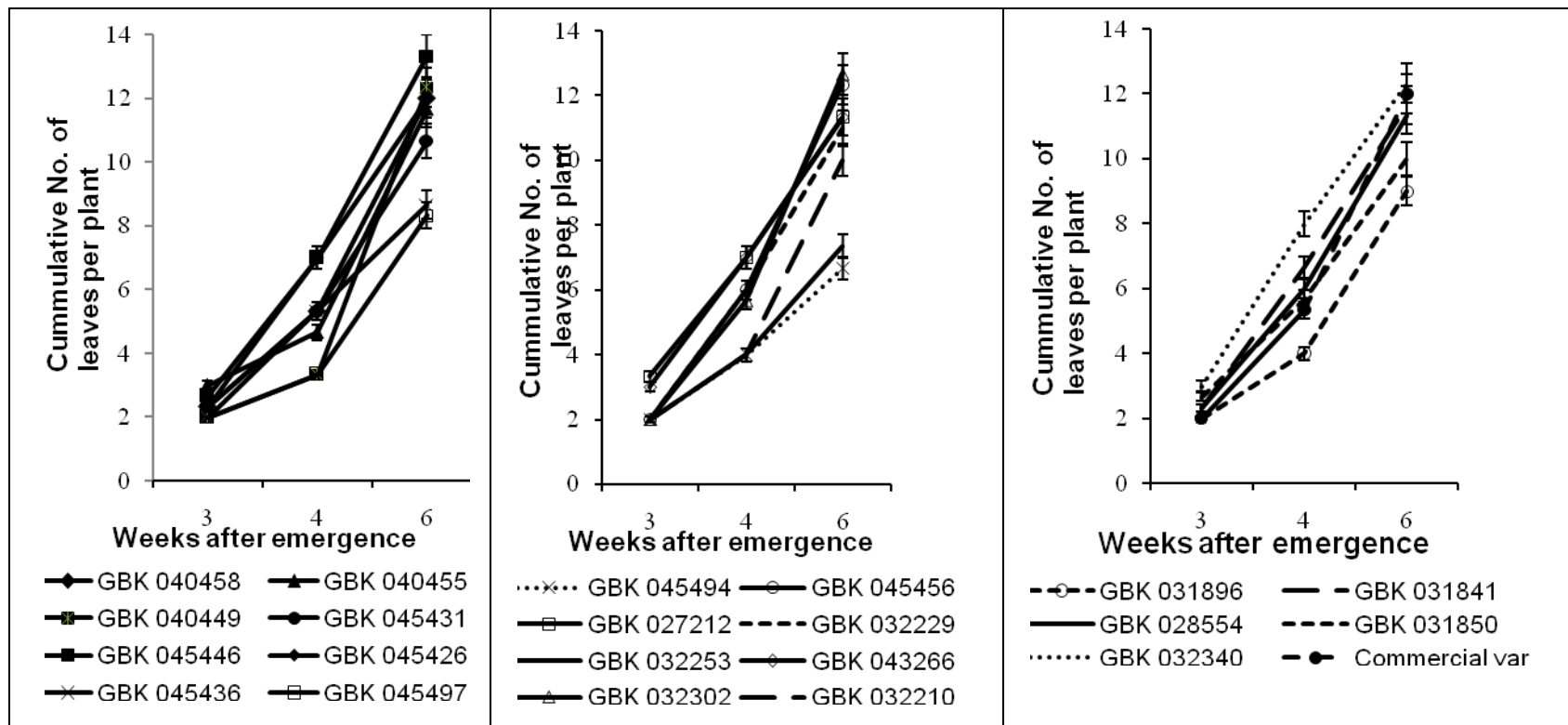


Figure 1: Cumulative number of leaves per plant for 22 spider plant (*Cleome gynandra* L.) genotypes (I = Error bars)
 (means of 10 plants per replicate x 3 replicates were used)

This was comparable to that of the commercial variety Saga, whereas 3 of the genotypes (GBK 045497, GBK 045494 and GBK 045436) had cumulative leaf number of between 6 to 8 leaves (Figure 1) within the same period. This implies that the genotypes with higher cumulative leaf number comparable to Saga could be candidates for promotion for vegetable production.

Leaves are the primary sites of photosynthesis in crop plants (18). Therefore, one might assume that the greater the number of leaves in a field, the better interception of sunlight and higher the yield (19, 20). The leaf number is most of the times correlated to the number of plants in a field. When the stand count is low, it is likely that the amount of leaves per unit area will also be low and hence low photosynthetic rate resulting in low productivity per unit area will be found, especially when dealing with a leafy vegetable (21) such as spider plant.

3.5 Days to pod formation

The number of days to pod formation also varied significantly ($P=0.05$) among genotypes (Table 2).

Table 2: Differences in number of days to pod formation, pods per plant, Seeds per pod and 100 seed weight for 26 spider plant genotypes evaluated under greenhouse conditions

Genotype	Days to pod formation	Pods per plant	Seeds per pod	100-seed weight
GBK-043595	45cde	6abcd	50abc	0.157d
GBK-040458	44bcde	3a	101c	0.145cd
GBK-040455	42abcd	5abc	124c	0.157d
GBK-040449	46de	6abcd	114c	0.15d
GBK-045431	38a	9d	120c	0.133bc
GBK-045446	40abc	4ab	170d	0.15d
GBK-045426	42abcd	6abcd	20a	0.14c
GBK-045436	39ab	7bcd	13a	0.133bc
GBK-045497	41abcd	4ab	48abc	0.123ab
GBK-045494	42abcd	7bcd	131c	0.153d
GBK-045456	43abcde	4ab	28a	0.128bc
GBK-027212	43abcde	5abc	103c	0.13b
GBK-032229	47e	5abc	28a	0.125abc
GBK-032253	40abc	8cd	14a	0.117a
GBK-043266	44bcde	4ab	58abc	0.145cd
GBK-032302	45cde	4ab	46ab	0.133bc
GBK-032210	45cde	5abc	46ab	0.137bc
GBK-031896	46de	6abcd	82bc	0.155d
GBK-031841	39ab	7bcd	114c	0.153d
GBK-032134	47e	4ab	91c	0.127bc
GBK-028554	48e	8cd	12a	0.147cd
GBK-031850	44bcde	4ab	80bc	0.157d
GBK-032340	46de	4ab	79bc	0.123ab
Commercial variety	40abc	4ab	21a	0.137bc
KS 1(Kisii)	47e	4ab	84bc	0.123ab
SN 1 (S.Nyanza)	41abcd	7bcd	102c	0.148cd
LSD	5.6**	3.4**	44.6**	0.009**

** = Significant ($P=0.05$)

Figures followed by the same letters along a column are not significantly different ($P=0.05$)

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182 Days to Pod formation varied between 38 and 48 days for GBK-045431 and, for GBK-
183 028554, GBK-032134 and GBK-032229, respectively. Genotype KS-1 took 47 days,
184 whereas GBK-032340, GBK-031896 and GBK-040449 took 46 days from planting to
185 podding. Saga took 40 days to pod, which was one week earlier than all the other genotypes
186 used in the study except for genotype GBK- 045431 that took 38 days. The beginning of pod
187 formation in spider plant significantly leads to loss of leaves with minimal production of new
188 leaves. The pods become an extra sink into which photosynthates are transported and may
189 limit the production of new leaves. In some species, the importation of resources into the
190 developing seeds is closely correlated with the capacity of leaves to export assimilates (22).
191 However, in Arabidopsis, the development of reproductive structures only minimally
192 influences leaf senescence, with organ age having a far greater effect. Selective pod
193 removal had almost no impact on individual leaf senescence in Arabidopsis, but overall plant
194 longevity was increased by 20–50 days (23). Therefore, genotypes in which pod formation
195 sets in early are not suitable for vegetable production if it results in senescence of the
196 leaves. The shorter period taken to pod formation might also not be a good indicator of a
197 genotype that should be used for seed production since this may mean a low total leaf yield
198 and hence limited photosynthetic capacity and hence reduced photosynthates necessary for
199 seed formation.

200 **3.6 Pods per Plant**

201 The number of pods per plant varied significantly ($P=.05$) among genotypes (Table 2). The
202 lowest number of pods per plant (3) was recorded in GBK-040458 and highest number of
203 pods per plant (9) was recorded in GBK-045431. Majority (69%) of genotypes had between
204 4 and 6 pods per plant. The primary components of seed yield are number of pods per plant
205 and seed weight. Seed yield is a complex character with polygenic inheritance having
206 positive or negative effects on yield component traits (24). In other crops, seed yield is
207 strongly correlated with the number of pods per plant (25). Taking this into account,
208 genotype GBK-045431 with 9 pods per plant would be expected to yield more seed than
209 genotypes that have a lower number of pods per plant, such as GBK 040458. However, this
210 can only be concluded after assessing the seed weight of different genotypes. Salehi et al.
211 (26) reported that the result of stepwise multiple regression analysis based on seed yield as
212 a dependent variable and other traits as independent variables, pods per plant explained
213 83.2% of the total variation suggesting that the number of pods per plant may be the main
214 factor determining seed yield.

215 **3.7 Seeds per Pod**

216 There were significant variations of genotypes for the number of seeds per pod (Table 2).
217 The highest number of seeds per pod (170 seeds) was recorded in GBK-045446 that had an
218 average of 4 pods per plant while the lowest number of seeds (12 seeds) per pod was
219 recorded in GBK-028554 with an average of 8 pods per plant. The number of seeds in a pod
220 can vary widely among; plant species (27), individual plants within a species (27, 28), and
221 fruits within a plant (29). Factors and processes affecting seed production might be achieved
222 with studies that incorporate variation at all these levels. The weight of each seed in a pod
223 increases with fewer seeds in a pod (27), as was found for some of the spider plant
224 genotypes evaluated; that had many pods per plant but with few seeds per pod. Esmail et
225 al. (30) has shown that characteristics such as number of pods per plant and seed yield per
226 plant can be used for selecting genotypes for seed production.

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229 **3.8 100-Seed weight**

230 The genotypic effect was significant ($P=0.05$) for 100-seed weight (Table 2). The heaviest
231 (0.157 g), seeds were produced by GBK-043595 (6 pods/plant; 50 seeds/pod), GBK-040455
232 (5 pods/plant; 124 seeds/pod), and GBK-031850 (4 pods/plant; 80 seeds/pod); whereas the
233 lowest seed weight of 0.117 g was detected on GBK-032253 (8 pods/plant, 4 seeds per
234 pod). The 100-seed weight is one of the most important criteria in seed quality
235 determination. It determines embryo size and seed storage for germination and emergence
236 (31). High 100-seed weight increases germination percent and seedling emergence (32, 33).
237 Thus, seed weight has a large effect on seed germination, seed vigor, seedling
238 establishment and yield production. For commercial purposes, genotypes with a high 100-
239 seed weight will be preferred by farmers as seeds are sold by weight. For vegetable
240 production, a high 100-seed weight will be important in ensuring high germination
241 percentages, hence high plant population resulting in high leaf yield per unit area
242

243 **4. CONCLUSION**

244 Genotypes; GBK-040449, GBK-027212, GBK-032210 and GBK-032340 that took between
245 4-7 days to emergence, had 40-50 percentage emergence and took more than 35 days from
246 planting to flowering (Annex 1) are considered desirable for vegetable production. Whereas
247 genotypes; GBK-040449, GBK-045494 and SN 1 that took more than 40 days from planting
248 to pod formation, produced 6-9 pods per plant having more than 100 seeds per pod and
249 100-seed weight of between 0.14 g to 0.16 g are considered attractive for seed production
250 (Annex 1). Genotype GBK 040449 was found to have traits desirable for both vegetable and
251 seed production (Annex 1). These genotypes, with desirable traits for vegetable and seed
252 production, are recommended for further evaluation under field conditions to corroborate the
253 greenhouse studies. In addition, given the low germination percent in the accessions
254 assessed, research is required to determine factors that could enhance germination of
255 spider plant.
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ANNEX 1: Summary of spider plant germplasm evaluation for desirable traits in vegetable and Seed production

Genotype	Vegetable production Parameters			Seed production Parameters			
	Days to emergence (4-7 days)	% Germination (40-50%)	Days to flowering (>35days)	Days to pod formation (>40days)	Pods per plant (6-9)	Seeds per pod (>100)	100-seed weight (0.14-0.16g)
GBK-043595			√	√	√	√	√
GBK-040458	√		√	√	√	√	√
GBK-040455	√		√	√	√	√	√
GBK-040449	√	√	√	√	√	√	√
GBK-045431					√	√	
GBK-045446	√			√	√	√	√
GBK-045426	√		√	√	√		√
GBK-045436	√	√			√		
GBK-045497	√			√			
GBK-045494	√			√	√	√	√
GBK-045456	√		√	√			
GBK-027212	√	√	√	√		√	
GBK-032229	√		√	√			
GBK-032253		√	√	√	√		
GBK-043266	√		√	√			√
GBK-032302	√		√	√			
GBK-032210	√	√	√	√			
GBK-031896			√	√	√		√
GBK-031841	√				√	√	√
GBK-032134	√		√	√			
GBK-028554	√		√	√	√		√
GBK-031850	√	√		√			√
GBK-032340	√	√	√	√			
Commercial var.	√		√	√			
KS 1	√		√	√			
SN 1	√		√	√	√	√	√
Total Count	22	7	19	23	14	10	13

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LEGEND:

√	Genotype with desirable traits scored for either vegetable or seed production		Genotype with all traits scored for Vegetable Production		Genotype with all traits scored for seed Production
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264 **REFERENCES**

- 265 [1] Ojiewo C, Tenkouano A, Oluoch M and Yang R. The role of AVRDC (The World
266 Vegetable Centre) in vegetable value chain. *Afr. J. Hort. Sci.* 2010; 3: 1-23
- 267 [2] Abukutsu-Onyango M. African indigenous vegetables: strategic repositioning in the
268 horticultural sector. 2nd Inaugural Lecture 2010. JKUA printers. ISBN 9966-923-31-4
- 269 [3] Tanaka T. Tanaka's Cyclopedia of Edible Plants of the World. Revised and edited by
270 Sasuke Nakao. 1976. First Edition, Keigaku, Tokyo.
- 271 [4] Debela HF, Jesse TN, Zemedu A and Nyangito MM Seasonal availability and
272 consumption of wild edible plants in semiarid Ethiopia: Implications to food security and
273 climate change adaptation. *J. Hortic. For.* 2011; 3(5): 138– 149
- 274 [5] Wilkes G. Native crops and wild food plants. *Ecologist*. 1977; 7:312-317.
- 275 [6] Chweya JA, Mnzava NA. Cat's whiskers: *Cleome gynandra* L. Promoting the
276 conservation and use of underutilized and neglected crops, 11. Rome: IPGRI; 1997
- 277 [7] Vorster HJ and Jansen Van Rensburg WS Traditional vegetables as a source of food in
278 South Africa: Some experiences. *African Crop Science Conference Proceedings*, 2005;
279 7:669-671
- 280 [8] Masinde WP and Agong GS. Plant growth and leaf N of spider plant under varying
281 nitrogen supply. *Afr. J. Hort. Sci.* 2011; 5: 36-49
- 282 [9] Kenya soil survey. Agro-Climatic Zone Map of Kenya. Ministry of Agriculture Kenya Soil
283 Survey. Nairobi. Kenya.1990
- 284 [10] Payne R, Murray D, Harding S, Baird D, and Soutar DM. Introduction to Genstat for
285 Windows. Rothamsted, UK: Lawes Agricultural Trust. 2006.
- 286 [11] K'opondo FBO, Muasya RM and Kiplagat OK A review on the seed production and
287 handling of indigenous vegetables (spiderplant, jute mallow and African nightshade complex)
288 In: MO Abukutsa-Onyango AN Muriithi VE Anjichi K Ngamau SG Agong A Fricke B Hau and
289 H Stutzel (Eds). *Proceedings of the third Horticulture Workshop on Sustainable Horticultural*
290 *production in the Tropics*. Maseno University, Maseno. 2005:42-48.
- 291 [12] Ochuodho JO, Modi AT and Beukes M. The dormancy and germination of *Cleome*
292 *gynandra* L. In: J.M. Wesonga (Ed). *Proceedings of the fourth workshop on Sustainable*
293 *Horticultural production in the tropics*. Moi University, Eldoret 2005:227-242.
- 294 [13] Nennich T. Vegetable Seed Germination and Soil Temperatures. Minnesota, Vegetable
295 IPM newsletter 2000; Vol. 2 No.3. Minnesota Extension Service, University of Minnesota.
296 USA.
- 297 [14] Anderson WK. Some relationships between plant population, yield components and
298 grain yield of wheat in a Mediterranean environment. *Austr. J. Agric. Res.* 1986; 37: 219-233

299 [15] Liu G, Marshall PD, Li Y, and Klassen W. Increased oxygen bioavailability, improved
300 vigor and germination of aged vegetable seeds. HortSci. 2012; 47(12):1714– 1721.

301 [16] Yamaguchi M. World vegetables: Principles, production and nutritive values. Van
302 Nostrand Reinhold, New York. 1983. 415 pp.

303 [17] Nonnecke IL. Vegetable Production. Van Nostrand Reinhold, New York. 1989. 656 pp.

304 [18] Nobel PS Physicochemical and environmental crop physiology (4th Edition) Elsevier
305 Inc. New York. 2009.

306 [19] Silvertooth JC. Row spacing, plant population, and yield relationships. Extension
307 Agronomist-Cotton, College of Agriculture, the University of Arizona. 1999. Accessed 28th
308 March 2014. Available: <http://ag.arizona.edu/crop/cotton/comments/april1999cc.html>

309 [20] Ross J. Plant stand architecture, photosynthesis and productivity. The radiation regime
310 and architecture of plant stand. Tasks for vegetation sciences 3. 1981; 3: 122-123

311 [21] Lawlor DW. Photosynthesis, productivity and environment. J. Exp. Bot., 1995; 46: 1449-
312 1461

313 [22] Wittenbach VA. Effect of pod removal on leaf photosynthesis and soluble protein
314 composition of field-grown soybeans. Plant Physiol. 1983; 73: 121–124.

315 [23] Nooden LD and Penney JP. Correlative controls of senescence and plant death in
316 Arabidopsis thaliana (Brassicaceae). J. Exp. Bot. 2001; 52: 2151–2159

317 [24] Azhar FM and Naeem M. Assessment of Cotton (Gossypium hirsutum) Germplasm for
318 Combining Abilities in Fiber Traits. J. Agric. Sci. 2008; 4:129-131

319 [25] Oyiga BC and Uguru MI. Interrelationships among pod and seed yield traits in Bambara
320 nuts (Vigna Subterranea L. Verdic) in the derived Savannah Agro-Ecology of South-Eastern
321 Nigeria under two planting dates Intl. J. Plant Breeding. 2011; 5 (2): 106 - 111

322 [26] Salehi M, Faramarzi A, Mohebalipour N. Evaluation of different effective traits on seed
323 yield of common bean (Phaseolus vulgaris L.) with path analysis. Am. Eurasian J. Agric.
324 Environ. Sci. 2010; 9: 52-54.

325 [27] Janzen DH. Interactions of seeds and their insect predators/parasitoids in a tropical
326 deciduous forest. In: P. W. Price (ed.). Evolutionary strategies of parasitic insects and mites.
327 Plenum Publishing Corp., New York. 1975.

328 [28] Stephenson AG. The regulation of maternal investment in an indeterminate flowering
329 plant (*Lotus corniculatus*). Ecology, 1984; 65:113-121.

330 [29] Mitchell R. Bruchid beetles and seed packaging by Palo Verdes. Ecology, 1977; 58:
331 644-651.

332 [30] Esmail AM, Mohamed AA, Hamdi A and Rabie EM. Analysis of yield variation in lentil
333 (*Lens culinaris* Medik). Ann. Agric. Sci. Moshtohor, 1994; 32: 1073-1087.

- 334 [31] Moshatati A and Gharineh MH. Effect of grain weight on germination and seed vigor of
335 wheat. *Intl. J. Agric. Crop Sci.* 2012; 4 (8): 458-460
- 336 [32] Noor-mohammadi GH, Siadat A and Kashani A. *Agronomy (cereal)*. Ahwaz University
337 Press. 2000. 446p
- 338 [33] Cordazzo CV. Effect of seed mass on germination and growth of three dominant
339 species in Southern Brazilian coastal dunes. *Braz. J. Biol.* 2002; 62:427-435
340
341
342