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Breeding runner bean for grain yield, disease resistance and short-day adaptation in eastern Africa

Kimani, P.M.[1], Mulanya, M.M.[1] & Narla, R.D.[1]
[1]Department of Plant Science and Crop Protection, College of Agriculture and Veterinary Sciences, University of Nairobi, P.O Box 29053-00625, Nairobi, Kenya

Corresponding author: pmkimani@uonbi.ac.ke

Abstract

Although runner bean (*Phaseolus coccineus* L.), also known as butter bean, is grown in high altitudes of eastern Africa where common bean (*Phaseolus vulgaris* L) is adapted, its productivity is poor because no improved short-day varieties are available. Farmers rely on low yielding landraces which are susceptible to diseases. However, the better yielding long-day vegetable type varieties are poorly adapted to tropical conditions. Our objectives were to develop breeding populations and select for new short day runner bean lines combining high grain yield potential with resistance to diseases and suitable for cultivation under tropical conditions. Four populations were developed from crosses between a long day variety (White Emergo) and four short-day grain type runner bean landraces at Kabete Field Station. The single crosses were advanced to F_5 generation as population bulks at Ol Jorok, Subukia and Kabete. Starting F_5, single plants were selected and advanced through single pod descent method. One hundred thirty-nine $F_{6.8}$ lines were evaluated in a randomised complete block design with three replicates at Kabete (1860 masl) and Ol Jorok (2300 masl) in 2012 and 2013. Scoring for plant vigour and diseases was based on 1 to 9, where 1-3 is resistant/ vigorous, 4-6 intermediate and 7 to 9 susceptible/ poor vigour. Results showed considerable variation for plant vigour, racemes per plant, grain colour, pod set, pod length, reaction to diseases and grain yield. . New lines were significantly more vigorous ($P<0.01$) compared with check varieties. Plant vigour scores varied from 1.7 to 3.7 among the new lines, compared with 2.7 to 5.7 for five check varieties. White Emergo showed significantly delayed second flowering ($P<0.01$) but failed to produce the first flush of flowers (50 days after planting), while all short day parents flowered normally within 36 to 53 days. Number of racemes per plant during the first flush of flowers varied from 3 to 13 with a mean of 7. Each raceme had 10 to 30 flowers. The new lines had white, black, purple, purple mottled and speckled grain types, suggesting recombination of grain colours of the parental lines. Major diseases observed were rust, common bacterial blight (CBB) and bean common mosaic virus (BCMV) at Kabete and Ol Jorok, and powdery mildew at Kabete. CBB and BCMV were most severe at both sites. However, the test lines showed resistant reactions to rust, CBB and BCMV. Grain yield varied from 2908 to 10,350 kg ha^{-1} with a mean of 6531 kg ha^{-1}. The new lines had a yield advantage of up to 67% compared with local short-day checks. The results indicated that new high yielding short-day runner bean varieties with resistance to major diseases and tropical adaptation can be developed from these lines.

Key words: Butter bean, flowering

Résumé

Bien que le haricot d'Espagne (*Phaseolus coccineus* L.), connu aussi sous le nom de haricot-beurre, est cultivé dans les hautes altitudes de l'Afrique de l'Est où le haricot commun (*Phaseolus vulgaris* L.) est adapté, sa productivité est faible car aucune des variétés améliorées de jours courts sont disponibles. Les agriculteurs comptent sur les variétés locales à faible rendement qui sont sensibles aux maladies. Cependant, le meilleur rendement des variétés de type végétal de long jour sont mal adaptées aux conditions tropicales. Nos objectifs étaient de développer des populations de reproduction et de sélectionner de nouvelles lignées de haricot coureur de jour court combinant le potentiel de rendement des céréales à haute résistance aux maladies et adaptées à la culture dans des conditions tropicales. Quatre populations ont été développées à partir de croisements entre une variété long-jour (Blanc Emergo) et quatre types de graine de jour-court de variétés locales de haricots coureur à la Station de Terrain de Kabete. Les croisements simples ont été avancés pour la génération F_5 que la population gonfle à Ol Jorok, Subukia et Kabete. A partir F_5, les plantes isolées ont été sélectionnées et ont progressé grâce à la méthode de descente de gousses. Cent trente-neuf lignées de $F_{6.8}$ ont été évaluées dans une conception de blocs aléatoires complets avec trois répétitions à Kabete (1860 m) et à Ol Jorok (2300 m) en 2012 et 2013. La notation de la vigueur et des maladies de plante a été fondée sur 1 à 9, où 1-3 est résistant / vigoureux, 4-6 intermédiaire et 7 à 9 sensibles/ manque de vigueur. Les résultats ont montré une variation considérable de la vigueur des plantes, des grappes par plante, la couleur des grains, la formation des gousses, la longueur de la gousse, la réaction aux maladies et le rendement en grains. . De nouvelles lignées sont nettement plus vigoureuses ($P < 0,01$) par rapport au contrôle des variétés. Les notations des vigueurs plantes variaient de 1,7 à 3,7 entre les nouvelles lignées, contre 2.7 à 5.7 pour cinq variétés testées. La variété de « Blanc Emergo » a montré une deuxième floraison considérablement retardé ($P < 0,01$), mais n'a pas réussi à produire la première vague de fleurs (50 jours après la plantation), tandis que tous les parents à jour court ont fleuri normalement dans les 36 à 53 jours. Le nombre de grappes par plante au cours de la première vague de fleurs varie de 3 à 13 avec une moyenne de 7. Chaque grappe avait 10 à 30 fleurs. Les nouvelles lignées avaient de types de grains de couleurs blanches, noire, violette, pourpre mouchetés et tachetés, suggérant la recombinaison des couleurs de grains des lignées parentales. Les principales maladies observées étaient la rouille, la brûlure bactérienne commune (CBB) et le virus de la mosaïque de haricots commun (BCMV) à Kabete et Ol Jorok, et le mildiou poudreux à Kabete. Le CBB et le BCMV étaient les plus sévères sur les deux sites. Cependant, les lignées de test ont montré des réactions résistantes à la rouille, au CBB et au BCMV. Le rendement en grains variait de 2908 à 10350 kg ha^{-1} avec une moyenne de 6531 kg ha^{-1}. Les nouvelles lignées avaient un avantage de rendement allant jusqu'à 67% par rapport à des contrôles locaux de jours courts. Les résultats indiquent que les nouvelles variétés de jours courts de haricots coureurs à haut rendement avec une résistance aux principales maladies et à l'adaptation tropicale, et peuvent être développés à partir de ces lignées.

Mots clés: Haricot beurre, la floraison

Background

Although runner bean is one of premium export vegetables from eastern Africa, current varieties are *long day* requiring extended light to stimulate flowering and pod formation. This requires expensive installation of electricity in production fields to provide additional light from 6 to 9PM, which is not practical for smallholder farmers (Kimani et al, 2009). Grain type runner bean is traditionally grown by smallholder farmers at high altitudes (>1500m) mainly for household consumption and sale in urban and rural markets. Recently, local factories have started to canner runner runner bean. However, the local varieties are low yielding and susceptible to diseases especially bean common mosaic virus, common bacterial blight and halo blight. Although local varieties are adapted to short-day conditions, their pods are tough, non-succulent and stringy and therefore not suitable for use as vegetables. There are improved grain type runner beans available to smallholder farmers, who rely mainly on local landraces.

Runner bean has received very little research attention. As a result, there are very few runner bean improvement programs in the world, and virtually none in eastern Africa (Kimani et al, 2009). Consequently all seed grown by exporting companies in Kenya is imported and expensive. The University of Nairobi has been developing new *short day* vegetable and grain runner beans which are tropically adapted and can be grown without extended light. The objective of this study was to evaluate advanced grain type lines for flower set under short-day conditions, yield potential and reaction to diseases.

Literature summary

Runner bean (*Phaseolus coccineus* L.) is an underutilized vegetable and grain legume. It was probably domesticated 2,200 years ago in the Tehuacan Valley in Mexico (IPBGR, 1983). Although it is cultivated as an annual, *P. coccineus* grows perennially in its natural habitats in the cool, humid uplands of Guatemala in altitudes of about 1,800 m. Hybrids of *P. vulgaris* × *P. coccineus* can be produced easily, while a reciprocal cross is produced only with difficulty. P. *coccineus* is an open-pollinated species with no barriers to self-pollination. It was probably introduced to Africa through Europe. In eastern Africa, runner bean is grown by smallholder farmers in high altitudes (>1800m) (Suttie, 1963). In United Kingdom, yields of runner bean pods average between 8.75 to 13.75 t ha-^{1}, although with efficient crop management yields can reach 37.5 t ha-^{1}(Day,1979). In Kenya, yields of dry mature seeds from smallholder production are estimated at 900 to 1120 kg ha-1 (Day, 1979). In Kenya, grain yield of 1904 kg ha-^{1} at 55,555 plants ha-1 were reported under experimental conditions at Kabete (Kahuro, 1990). Data on pod yield of long day varieties grown by exporting companies in Kenya was not available.

Study description

Four populations were developed from crosses between a long day variety (White Emergo) and four short-day grain type runner bean landraces at Kabete Field Station. The landraces were Nyeri, Kin 1, Kin 2 and Kin 3. The single crosses were advanced to F_5 generation as

population bulks at Ol Jorok, Subukia and Kabete. Starting F_5, single plants were selected and advanced through single pod descent method. One hundred thirty-nine $F_{6.8}$ lines were evaluated in a randomized complete block design with three replicates at Kabete (1860 masl) and Ol Jorok (2300 masl) in 2012 and 2013. Parental lines were used as checks. Data was collected on flower set, duration to flowering, reaction to diseases and grain yield, and analyzed using Genstat software version 14. Scoring for plant vigour and diseases was based on 1 to 9, where 1-3 is resistant/vigorous, 4-6 intermediate and 7 to 9 susceptible/ poor vigour

Research application

Considerable variation in flowering was observed among the test lines (Table 1). White Emergo failed to set flowers during the first flush at Ol Joro-orok which occurred after 49 to 53 days after planting. In contrast, the test lines flowered in 46 to 54 days at Kabete. White Emergo produced an average of one raceme per plant at Kabete Field Station during the first flush of flowering (Table 1). During the second flush which occurred about 110 days after planting, White Emergo produced 2 racemes at Ol Joro-orok and none at Kabete. In contrast, the test lines produced 2.8 to 14.4 races with a mean of 7.2 racemes at Ol Jorok during the first flush. At Kabete number of racemes per plant during the first flush of flowering varied from 0 to 7.1 with a mean of 2.7. During the second flush of flowering, number of racemes per plant varied from 1 to 11 with a mean of 5.3 at Ol Joro-orok. Two checks (OLJ DWF 1 and 3) failed to produce a second flush of flowers. At Kabete, number of racemes per plant varied from 0 to 2.4. Twenty lines and tow check varieties (Nyeri1 and OLJ DWF 3) failed to produce the second flush of flowers at Kabete. The poor flower set at Kabete was probably due to severe mid-season moisture stress which caused abortion of flower buds.

Table 2 shows the plant vigour, reaction to diseases and grain yield of the best lines at the two locations. Plants were generally more vigorous at Ol Joro-orok probably due to the more fertile soils, cooler and wetter conditions which favour growth of runner beans. Diseases also were more severe at Ol Joro-orok. However, there were significant differences among the test lines for reaction to diseases. Test lines showed higher levels of resistance compared with checks. The new lines yielded far better that all the checks (Table 2). Twenty-seven new lines had more 100% grain yield advantage compared with the best check. The results indicate that selection method was highly effective in developing new short-day runner bean lines combining resistance to disease, plant vigour and high grain yield. Release of the new lines can greatly improve productivity and commercialisation of runner beans in highlands of eastern Africa.

Table 1. Number of racemes plant-[1] of advanced grain type runner bean lines during the first and second flush of flowering at Ol Jorok and Kabete, 2013.

Genotype	Racemes plant-[1]						Mean
	Days to flowering		First flowering		Second flowering		
	Ol Jorok	Kabete	Ol Jorok	Kabete	Ol Jorok	Kabete	
KAB-RB13-303-146	50.3	49.3	14.4	5.1	5.3	0.8	6.4
KAB-RB13-301-170	50.7	50.7	13.6	2.9	6.8	0.0	5.8
KAB-RB13-321-185	51.7	51.7	12.0	1.7	5.1	1.0	5.0
KAB-RB13-75-6	51.3	50.3	11.8	4.6	7.5	0.2	6.0
KAB-RB13-46-19	50.3	51.7	11.7	3.3	4.3	0.7	5.0
SUB-OL-RB13-133-243	50.3	51.3	11.3	3.2	5.7	0.7	5.2
KAB-RB13-379-147	51.7	52.3	11.0	3.0	6.5	0.9	5.4
KAB-RB13-120-123	50.3	48.3	10.8	3.7	7.8	0.4	5.7
KAB-RB13-403-153	51.0	51.0	10.8	7.1	10.8	0.3	7.3
SUB-OL-RB13-96-237	50.7	51.7	10.8	4.4	7.2	0.1	5.6
KAB-RB13-326-207	51.0	50.3	10.8	6.1	11.3	0.7	7.2
SUB-OL-RB13-178-239	52.0	50.0	10.7	4.5	2.8	0.1	4.5
KAB-RB13-341-143	50.7	52.3	10.6	3.1	7.4	0.4	5.4
OLJ DWF 1	50.7	52.3	9.0	4.2	0.0	0.2	3.4
NYERI 1	52.3	50.7	2.0	2.0	1.3	0.0	1.3
KIN 2	51.0	51.0	5.0	1.5	3.3	0.3	2.5
KIN 3	52.3	49.7	1.0	1.4	2.4	1.0	1.5
OLJ DWF 3	53.3	53.3	3.9	1.0	0.0	0.0	1.2
White Emergo	-	55.0	0.0	1.0	2.0	0.0	0.8
Trial mean	50.7	50.8	7.2	2.7	5.2	0.6	3.9
$LSD_{0.05}$	1.9	2.6	3.0	1.3	2.8	0.4	-
CV (%)	0.7	2.5	33.9	12.5	20.6	9.1	-

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Table 2. Plant vigour, reaction to diseases and grain yield of new runner bean lines grown at Ol Jorok and Kabete in 2013.

Genotype	Plant vigour		BCMV		CBB		Rust		Grain yield (kg ha^{-1})
	OJ#	KAB#	OJ	KAB	OJ	KAB	OJ	KAB	
SUB-OL-RB13-323-2	1.7	1.7	3.0	1.0	1.7	1.0	1.0	1.0	9908
KAB-RB13-312-160	1.7	2.3	3.0	1.0	2.0	1.0	1.0	1.0	9883
KAB-RB13-310-162	2.3	1.7	3.3	1.0	3.3	1.0	1.3	1.0	9575
KAB-RB13-343-184	2.3	3.0	2.7	1.0	1.7	1.0	1.0	1.0	9514
KAB-RB13-405-196	2.3	3.0	3.0	1.0	3.3	1.0	1.0	1.0	9465
KAB-RB13-364-212	3.7	1.7	2.3	1.0	1.7	1.7	1.3	1.0	9287
KAB-RB13-297-144	3.0	3.0	3.0	1.0	2.3	1.0	2.7	1.0	9199
KAB-RB13-303-146	2.3	3.7	3.0	1.0	1.7	1.7	1.3	1.0	9019
KAB-RB13-46-124	1.7	3.0	2.7	1.0	2.3	1.0	1.3	1.0	8933
KAB-RB13-329-163	2.3	3.7	3.7	1.0	3.3	1.0	1.0	1.0	8910
KIN 3	5.7	3.7	4.7	1.0	5.0	1.0	3.0	1.0	3947
KIN 2	2.3	3.7	4.0	1.0	2.7	1.0	2.0	1.0	2573
OLJ DWF 1	3.7	3.7	4.0	1.0	4.3	1.0	2.3	1.3	-
NYERI	3.0	3.0	3.7	1.0	3.0	1.0	1.0	1.3	-
OLJ DWF 3	2.7	4.3	4.0	1.0	3.7	1.0	1.7	1.0	-
Trial mean	2.1	2.6	2.9	1.0	2.3	1.1	1.4	1.1	6523
$LSD_{0.05}$	1.2	1.2	0.4	0.9	0.6	0.2	0.2	0.1	2469
CV(%)	9.8	9.1	4.0	9.1	6.4	5.4	2.7	4.2	4.4

OJ=Ol Joro-orok, KAB= Kabete

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