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RESEARCH PAPER

Comparison of phenological phases and morphological traits in grain and vegetable soybean types and their relation with yield

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Abstract: Ten genotypes consisting of both vegetable (AGS 447, AGS 459, AGS 460)) and grain types (Kalitur, DSb-21, DSM, KHSb-2, DB-local, DSb-15 and JS-335) were sown during *kharif* 2015 with an objective of studying the phenological phases and morphological traits and comparing between these two types of soybean and their relation with seed yield. The data on phenological phases revealed that the vegetative phases (VE, V1, V2, V3) were late in vegetable types in contrast the reproductive phases (R1, R2, R3, R4, R5, R6, R7 and R8) in vegetative types were squeezed. This is a typical feature of vegetable types compared to grain soybean types. The yield of grain soybean types was higher compared to vegetable types at R8 stage. This was mainly attributed to longer duration of reproductive phases of grain soybeans followed by increased yield attributes like higher number of pods/plant, higher no. of seeds per pod and better canopy architecture of the grain soybean types. Thus grain and vegetable soybean differed distinctively in phenology and morphological traits. Among the grain soybeans, Kalitur yielded highest followed by JS 335. Among the vegetable types AGS 447 gave higher yield.

Key words: Golden bean**,** Grain, Phenology, Vegetable soybean

Introduction

Soybean, the "Golden Bean" of the twentieth century, has emerged as an important commercial crop in many countries and international trade of soybean is spread globally. Several countries such as Japan, China, Indonesia, Philippines, and European countries are importing soybean to supplement their domestic requirement for human consumption and cattle feed. Soybean is gaining popularity on account of its unique characteristics and adaptability to varied agro-climatic conditions. It has unmatched composition of 40 per cent protein and 20 per cent oil and nutritional superiority on account of containing essential amino acids, unsaturated fatty acids, carbohydrates, vitamins and minerals. Soybean protein is rich in valuable amino acid lysine (5%) in which most cereals are deficient. In addition, it contains a good amount of minerals, salts and vitamins (thiamine and riboflavin) and its sprouting grains contain a considerable amount of Vitamin C. Two types of soybean are common viz., grain and vegetable. Grain soybean is more popular because of its nutritional and industrial value. Whereas, vegetable soybean is meant for daily domestic purpose and is consumed fresh. The major quality *p*arameters of vegetable soybean are turgid weight and sweetness at R6 stage of harvest of the pods. Though grain and vegetable soybean types belong to same family and origin both are architecturally and phenologically distinct and their relationship to the yield varies. Both types of soybean need to be improved to meet the growing demand of industry as well domestic. Hence, an attempt has been made to study the phenological phases and morphological parameters in both types of soybean for crop improvement.

Material and methods

Ten genotypes of both vegetable (AGS 447, AGS 459 and AGS 460) and grain type (Kalitur, DSb-21, DSM, KHSb-2, DB-local DSb-15 and JS-335) soybean were sown during *kharif* 2015 in three replications following the RBD at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The experimental site consisted of medium black clay loam soil and the recommended package of practice of the soybean for the region was followed. Five plants were randomly selected and tagged in each genotype to record the various observations related to growth and development. Field observations included plant height, number of branches per plant, days to different phenologcal stages (VE, V1, V2, V3, R1, R2, R3, R4, R5, R6, R7 and R8), photosyntetic rate and yield and yield components. The data was analysed by Standard Fisher's method of analysis of variance (ANOVA) and result interpretation of experimental data as suggested by Gomez and Gomez (1984).

Results and discussion

Morphological characters such as plant height, number of leaves, number of nodes, and number of branches play a vital role in the infrastructure of the plant. These traits are significantly influenced by genetic makeup of the plants and as well as by the environmental variables and cultural practices (Comlekcioglu and Simsek, 2011). The yield potential of any genotype is determined by the infrastructure of the plant. The data on plant height at 30 and 60 DAS and at harvest indicated significant differences among the soybean genotypes. Thus wide variability among the genotypes was evident. DB-Local recorded significantly maximum height at all the stages as it followed an indeterminate growth habit. Whereas, all the vegetable soybean genotypes (AGS 460, AGS 459 and AGS 447) were distinct with dwarf growth habit.

The genotypes which had higher yield (DSM, Kalitur, DSb-21 and JS-335) had moderate to higher plant height. The

results of present investigation are in agreement with earlier workers (Bangar, 2003) and have shown positive relationship between the plant height and seed yield. Another important morphological trait which has relevance to the performance of productivity is number of branches as they bear the assimilatory organs. The number of branches per plant differed significantly among the genotypes and was maximum in DB-Local at all the crop growth stages (Table 1). Malik *et al.* (2012) and Ali *et al.* (2013) opined that number of branches have positive association with seed yield in soybean and further they reported that for increasing yield potential there is necessity of improving number of branches. The vegetable genotype AGS- 460 had least number of branches resulting in low pod yield. These results are in conformity with that of Akparobi (2009) and Priyanka (2014) who reported that number of branches have positive correlation with the yield in grain soybean.. The entire vegetable soybean in this study has a shy branching with fewer yields compared to grain soybean.

Photosynthetic rate during the crop growth period is of immense important as it directly contributes to current photosynthates to developing pods. The genotypes with high photosynthetic rate would have higher pod yield. In this present study the result obtained was contrary to this as the genotypes (DSM and DB-Local) with higher photosynthetic rate recorded lower seed yield indicating that the yield is not solely determined by the leaf photosynthetic rate but is determined by the canopy and its spread. The genotype DSb-21 had lower photosynthetic rate but recorded a higher seed yield this can be due to the higher partitioning efficiency with better infrastructure of the plant. Neither robust growth like DB-Local (creepy nature) and KHSb-2 (tall) nor the growth like vegetable AGS soybean types (dwarf) suitable for higher grain yield. The genotypes JS-335, Kalitur and DSb-21 were identified as ideal grain soybean ideotypes with moderate architecture for higher grain yield.

Monitoring crop phenology provides essential information for crop management, as well as for understanding regional to global scale vegetation dynamics. Days to emergence (VE) ranged from 5.3-11.3 days in the different genotypes. The genotype DSb-15 (5.3) was early to emerge followed by genotype JS-335 (5.7). Whereas, late emergence was noticed in AGS vegetable genotypes recording nearly 11 days. In general the vegetable genotypes took more number of days for emergence compared to grain soybean types, which can be attributed to the larger seed size of vegetable soybean genotypes which is significantly large compared to grain soybean genotypes. Smaller the seed size higher is the germination rate requiring less number of days for emergence (VE). The other vegetative phases VC, V1, V2 and V3 delayed in vegetable soybean types by 4-5 days than grain soybeans except the KHSb-2 which was on par with vegetable types.

R1 (beginning bloom) and R5 (beginning seed) can vary from 18 to 40 days depending on genotype and environment (Purcell *et al.,* 2014). R1 stage (beginning bloom) when at least one flower opens on the main stem, was occurred early within 30-34.7 DAS in vegetable soybeans AGS-460, AGS-459 and AGS-447 except the KHSb-2. After pollination, pods begin to develop and are usually visible within five days.

Pods reach an almost full width while the developing embryo is still very small. The genotype, DB-Local required significantly more number of days to full pod compared to all genotypes. The genotype DSM was on par with DB- Local. The genotype AGS-460 recorded least number of days to reach R4 which was on par with AGS 447 and AGS 459. After R5, seeds enter a period of rapid linear dry matter accumulation. The length of this period is also variable, between 18 and 57 days (Zhang, *et al.,* 2010). The genotype DB-Local and rest of the grain soybean types took significantly more number of days to attain full seed (R6). Whereas, the vegetable soybean types were found to be early in reaching the R6 stage. Reproductive phases in contrast to vegetative phases in vegetable types were distinctively early when compared to grain types (Table 3). This is a typical feature of vegetable soybean for harvesting of

Table 1. Comparison of grain and vegetable types for the morphological traits and photosynthetic rate at different stages

Genotypes	Plant height (cm)			Number of branches			Photosynthetic rate
	30 DAS	60 DAS	Harvest	30 DAS	60DAS	Harvest	(ìmol CO_2 m^{-2} s^{-1})
Grain Soybean genotypes							
Kalitur	17.8^{d}	58.1^{b}	87.4^{c}	5.60^{d}	19.27^{c}	22.73^{d}	21.5 $^{a-c}$
DSb-21	18.4^{c}	57.2^{b}	85.4^{d}	6.20^{c}	20.13^{c}	23.73^{c}	20.5 ^{c}
DSM	17.9^{cd}	57.3^{b}	86.7^{cd}	6.47^{c}	21.67^{b}	24.00^{c}	25.2 ^{a}
KHSb-2	20.7^{b}	67.0^{b}	95.7^{b}	7.33^{b}	23.80^{a}	25.40^{b}	21.5 $^{a-c}$
DB-Local	21.4^{a}	86.9^{a}	100.8^{a}	7.93^{a}	21.87^{b}	26.13^{a}	24.7 ^{a}
DSb-15	18.1^{cd}	56.9^{b}	86.4^{cd}	4.93^{ef}	17.73^{d}	23.47^{c}	22.7^{a-c}
JS-335	18.1^{cd}	57.3^{b}	86.3^{cd}	5.40^{de}	18.20^{d}	23.27^{cd}	23.4 ^{ab}
Vegetable Soybean genotypes							
AGS 447	10.1^{e}	34.5^{c}	44.3^{e}	4.40^{fg}	10.07^{e}	13.67^{e}	22.9^{ab}
AGS 459	9.9^{e}	34.8^{c}	45.0^{e}	4.47^{fg}	10.27^{e}	12.93^{f}	21.9 $^{a-c}$
AGS 460	10.0^{e}	35.0^{c}	44.9^{e}	4.00^{g}	10.87^{e}	12.87^{f}	22.0 ^{bc}
Grand Mean	16.2	54.5	76.3	5.67	17.39	20.82	22.62
S.Em±	0.2	5.1	0.5	0.21	0.33	0.24	1.04
C.D. (P=0.05)	0.5	15.1	1.6	0.62	0.98	0.70	3.10

Values in the column followed by the same letters do not differ significantly by DMRT

Table 2. Comparison of grain and vegetable types for yield and yield components of different soybean

Genotypes	No.of pods Plant^{-1}	No.of seeds Pod^{-1}	Seed weight (g plant^{-1})	Seed yield (q ha $^{-1}$)	Test weight (g)
Grain Soybean genotypes					
Kalitur	67.7^{ab}	2.6^{abc}	14.0^{bc}	43.1^{a}	11.2^{e}
DSb-21	60.9^{b}	2.7^{ab}	12.8^{c}	40.2^{ab}	10.9^{ef}
DSM	62.6^{ab}	2.5^{abcd}	9.8^{de}	30.2^{d}	15.5^{d}
KHSb-2	59.7^{b}	2.3^{cd}	10.0^{d}	31.3^{cd}	15.5^{d}
DB-Local	74.7^{a}	2.7^{abc}	7.7^{e}	23.2^{e}	8.8^{f}
DSb-15	62.9^{ab}	2.5^{bcd}	12.6^{c}	38.0^{abc}	18.9^{c}
JS-335	60.4^{b}	2.9^{a}	12.8^{c}	44.2^{a}	12.9^{e}
Vegetable Soybean genotypes					
AGS 447	36.3^{c}	2.2^{d}	15.9^{ab}	33.8^{bcd}	35.3^{a}
AGS 459	29.3^{c}	2.2^{d}	14.9^{bc}	32.1^{cd}	31.3^{b}
AGS 460	32.5^{c}	2.2^{d}	18.1^{a}	36.7^{abcd}	34.3^{a}
Grand Mean	54.7	2.5	12.9	35.3	19.5
S.Em±	3.9	0.1	0.7	2.3	0.7
C.D. (P=0.05)	11.6	0.3	2.2	6.8	2.2

number of days to reach maturity. However, grain soybeans took more number of days for maturity compared to vegetable soybean types.

Among the genotypes in the present study, DB-Local followed an indeterminate growth habit which associated with the lowest yield. Kalitur showed a semi-determinate growth habit with some amount of trailing habit gave yield on par with JS-335 thus semi-determinate and determinate growth are better from the point of higher yield.

Yield is a complex polygenic trait. The yield attributing characters like number of pods per plant, number of seed per pod, seed weight per plant, seed yield per plot, test weight significantly differed. The genotype DB-Local recorded higher number of pods per plant followed by Kalitur. But, DB-Local recorded a low seed yield compared to other five grain genotypes because of the smaller seed size indicated by smaller test weight (Table 3). Another reason for lower yield in DB-Local might be

Table 3. Genotypic variations in the phenological sages (Days to VE, VC, V1, V2, R1, R2, R3, R4, R5, R6, R7, R8 and harvest) in soybean

Genotypes	VE	VC	V1	V2	R1	R2	R3	R4	R5	R6	R7	R8	Harvest
Grain Soybean genotypes													
Kalitur	6.3 ^{cd}	12.7 ^{d}	17.7^{c}	21.3^{b}	37.7^{b}	38.7^{b}	47.7^{d}	54.3^{d}	63.3^{e}	73.3^{e}	81.7^{d}	90.7^{c}	98.3^{f}
DSb-21	6.0 ^{cd}	12.7^{d}	16.7^{cd}	21.3^{b}	38.7^{b}	39.7^{b}	48.7^{c}	58.3^{c}	66.3^{d}	77.3^{d}	85.7^{c}	95.7^{b}	101.7^{e}
DSM	6.3 ^{cd}	12.7^{d}	17.3^{cd}	21.3^{b}	38.3^{b}	39.3^{b}	50.7^{b}	60.3^{b}	67.7^{c}	77.7^{d}	87.7^{b}	98.0^{a}	103.7^{c}
KHSb-2	7.7 ^{b}	16.7^{c}	20.3^{b}	25.3^{a}	41.7^{a}	42.7^{a}	51.3^{b}	61.0^{b}	70.7^{b}	80.7^{b}	90.3^{a}	98.3^{a}	110.7^{a}
DB-Local	7.0 ^{bc}	16.3^{c}	20.3^{b}	25.7^{a}	42^{a}	42.7^{a}	52.7^{a}	62.3^{a}	74.3^{a}	82.0^{a}	88.7^{b}	96.0^{b}	108.3^{b}
DSb-15	5.3 ^{d}	11.7^{de}	16.3^{d}	21.7^{ab}	38.3^{b}	39.3^{b}	47.3^{d}	57.3^{c}	66.3^{d}	79.3^{c}	86.3^{c}	96.7^{b}	102.7^{d}
JS-335	5.7 ^{d}	11.3^{e}	15.3^{e}	20.0^{c}	35.3^{c}	36.3^{c}	40.7^{e}	48.3^{e}	59.7^{f}	70.7^{f}	79.7^{e}	90.3^{c}	97.3^{g}
Vegetable Soybean genotypes													
AGS 447	11.7^{a}	21.3^{a}	22.0^{a}	26.0^{a}	34.7^{c}	35.7^{c}	39.0^{f}	46.3^{f}	56.0^{g}	66.7^{g}	75.7^{f}	85.7^{d}	90.7^{h}
AGS 459	10.7^{a}	18.7^{b}	22.7^{a}	25.7^{a}	34.7^{c}	35.7^{c}	40.3^{e}	48.3^{e}	56.3^{g}	66.3^{g}	75.3^{f}	84.3^{e}	90.3^{h}
AGS 460	11.3 ^{a}	18.0^{b}	22.3^{a}	25.7^{a}	30.3^{d}	31.3^{d}	38.7^{f}	46.3^{f}	54.3^{h}	63.7^{h}	71.3^{g}	82.3^{f}	90.7^{h}
Grand Mean	7.8	15.2	19.1	23.4	37.13	38.13	45.7	54.3	63.5	73.8	82.2	91.8	99.4
S.Em±	0.35	0.37	0.33	0.29	0.39	0.39	0.29	0.38	0.33	0.33	0.39	0.35	0.30
C.D. (P=0.05)	1.03	1.08	0.97	0.86	1.17	1.17	0.87	1.13	0.99	0.98	1.16	1.05	0.90

Values in the column followed by the same letters do not differ significantly by DMRT G: Grain soybean V: Vegetable soybean

VE- Days to plant emergence
VC - Days to cotyledon or unifoliate stage
V1 - Days to first Trifoliate stage
V2 - Days to second Trifoliate stage
R1 - Days to beginning bloom
R2 - Days to full bloom
R3 - Days to beginning pod
R4 - Days to full pod
R5 - Days to beginning seed
R6 - Days to full seed
R7 - Days to beginning maturity

green pods at R6 stage. Accordingly the R6 stage in most of the vegetable soybean particularly AGS genotypes attained around 66 -70 days where pods are completely filled with larger green beans. These AGS genotypes are exclusively developed as vegetable genotypes by AVRDC (Koti *et al.,* 2013)

The stage R8 (full maturity) when 95 per cent of the pods have mature pod colour was attained in vegetable soybean types in 82-86 days whereas in grain soybean types it was in the range of 90-98 days. Physiological maturity occurs between stages R7 and R8 when pods lose their green colour and become yellow. Leaflets and petioles also turn yellow at this time and abscise. Among grain soybean genotypes, JS-335 was found to be early maturing and the genotype, KHSb-2 took significantly more

later formed pods remained unfilled followed by the smaller sink size. Significantly lower number of pods per plant was recorded by the vegetable soybean genotype, AGS 459, which was on par with AGS 460 and AGS 447. Genotypes with more number of pods per plant have not yielded high seed yield because the seed yield further depends on other parameters such as seeds per pod, seed weight and shelling percentage. Genotypes with maximum two to three seeded pods resulted in higher seed yield as in the case of JS-335, Kalitur and DSb-21. These results are similar with the earlier report by Thaworn *et al.* (2011). Vegetable soybean genotype AGS 460 had a higher seed weight per plant but it doesn't result in a higher seed yield because of the lesser number of pods and seeds per pod.

Conclusion

Thus, from the study it was inferred that grain and vegetable genotypes were distinct in morphological traits and phonological stages. A positive correlation was observed in the case of yield and yield related traits *viz.,* number of pods per plant, number of seeds per pod, seed weight (g plant^{-1}) and test weight (g). Plant height was also found positively correlated with yield. There has to be more scope for longer vegetative phases than reproductive phases in vegetable types and is vice versa in grain soybean types. Keeping this feature, the programme of development of vegetable soybean/grain soybean is to be targeted.

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