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Genotype season interaction effects on the performance ofsoybean lines

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Abstract

The purposeofthis study wastoobtaininformationon yield potentialof soybean linestestedinthe first dryseason(MK1) and theseconddryseason(MK2). Theinformationwas used to select soybean lines which are most stable under the two different seasonsto bereleased as varieties. This research was conductedintwogrowing seasonsfrom March toSeptember2014 in Bogor.The genetic materialsused were 7promising linesand3nationalvarieties. The designused wasa randomized completelyblockdesignwithgenotypeastreatmentrepeated3timesineach season. Observations were madeonagronomic charactersof plant height, numberof branches, number of nodes, number of pods, number oftotalpods, days to flowering, days to harvesting, weight of 100grains, grain weightper plant, andproductivity. The results showedthatWeightperplantandproductivitywas notaffectedbythe interactionbetweengenotypeandseason. The average productivityforallgenotypesin the first seasonwas3.1tonsha-1 is greaterthanthe secondseasonthat is equal to1.8tonsha^{-1}.SC-1-8 was recommeded for both seasons.

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Introduction

Soybean(*Glycine max*(L.) Merr.)isone ofthe majorcommoditywith high demand inIndonesiabecause it is an importantsourceof vegetable proteintosupport ofnational food security. According to Truong *et al*. (2013), soybeansare usedasraw materialsinagroindustriesassoybean has protein up to 40%.

Soybean demandcontinues toincrease along withpopulation growthandthe needs ofindustrial raw materialssuch as tofu, soy sauce, tempeh, soymilk, fermented soy,and snacks(Komalasari, 2008). However, soybean demand is not metbecauseIndonesian nationalsoybeanproductioncontinuesto decrease. One ofthe reasons ofthe decline inthe nationalsoybeanproductionisreduction inplanting areas. In 2012soybeanplanting areaonlyreached570 495hawith a total production of851 647tons much smaller whencompared to1992whichreached1,151,079ha. The nationalsoybeanneedsamounted to2.2milliontonsperyear(SCA, 2012). Asa resultof domesticsoybeanproductionis notable to meetthe growing need. The cause ofthe declineof soybeanplanting areaisland resourcecompetitionwithothercommoditieswhichhave a highereconomicvaluethansoyandproductivedue toland conversion.

Another factorcauses lowproductivity ofsoybean wasdue tothe influence ofenvironmental conditionsinthe tropics whichareless supportive ofthatgrowthis not as goodas soybeancropinsubtropicalregions. The use oflow-qualityseeds, in appropriateplanting time andless optimalnutrient management, less effective pestcontrol, andless than optimalposth-arvesthandling (Sumarno*et.al.*,2007).

Efforts toincreasesoybeanproductioninIndonesia requiresthe availability ofimproved varietieswhich arehigh yielding, responsive to theimprovement ofenvironmental conditions, as well as havingothersuperior characteristics(Arsyad*et al.*, 2007).

Development of high-yielding varietiesthroughplant breeding could be conductedbyselection on thegermplasmavailablein theimprovementof yieldandcropadaptation(Wirnas*et al.*, 2012). Development ofnew varietiesrequires apopulation whichhas ahigh genetic variability(Husni*et al.*, 2006; Sihaloho *et al.*, 2014).Breedingeffortstoobtainhigh-yieldingvarietiesandadaptiveinvariousenvironmentsa re now widelyperformed,oneisthrough hybridization followed by selection.

Yield trial is an important stepafterselectiontodeterminethepromising linestobe released ashigh-yielding varieties. Soybean varietiesare generallydevelopedtohavefavorableproperties, among others: (1) highyield, (2) resistant topestsanddiseases, (3) early maturity, and(4) the seed quality suitable for consumer preference(MOA,2007).

Department of AgronomyandHorticulture,IPB has conductsoybean breedingthroughhybridization and selectionthat producesshadetolerantlines. Development ofshadetolerantlinesarebreedingeffortstooptimize the use oflandunderplantationstandson theimmaturephase(TBM) (Yunita*et al.*, 2009).Thisshade-tolerant lineshave been testedinshadedconditionsandneedfurthertestingin differentenvironmentsunshadedandseasontodetermin ethe stability of yield potential.

In the upland of some parts of Indonesia, soybean can be planted two seasons a year. Soybean productionis influencedbyseason, genotype,andinteractionbetweengenotypewith theseasons.

The proportion of line phenotyperespectivelyis caused byenvironmentalfactorsgenotypeandgenotype xenvironmentinteractions. Genotypebyenvironmentinteractionis usefulfor determiningthe areaof adaptationof agenotypeina particularenvironment, determine theadaptabilityandstability ofgenotypes(Sneller*et al.*, 1997)andto assess the roleof environmental factors onthe geneticpotential ofagenotype(Vargas *et al.*,1998; Rao*et al.*, 2002).

The purposeofthis study wastoobtaininformation on yield potentiallinesevaluatedinthe dryseasonone(S1) and theseconddryseason(S2).

Materials and methods

Locations

The experiment was conductedat the Center forResearchandDevelopment of BiotechnologyandAgriculture Plant GeneticResources, Cimangguandexperimental garden, Leuwikopo, Bogor, Indonesia. This research was conductedintwogrowing seasonsfrom March toSeptember2014.

Genetic materials

The material usedwas7IPBpromising lines, namelySC-1-8, CG-22-10, SP-30-4, SC-21- 5, SC-56-3, PG-57-1, SC-54-1, andthreenational varieties as check, namelySibayak, Tanggamus,andWilis.

Experimental design and Statistical analysis

The experimental designused for each growing season wasa complete randomizedblock design(RCBD) with three replications. Crop management was optimal in terms of fertilization, irrigation, and weed and pest control.Observations were madeonagronomic characters.Analysis of variance (ANOVA) was carried out detect significant effects among the genotypes

Results and discussion

Climate conditions in the growing seasons

There was a difference in rainfall, humidity,andduration of irradiationreceived by thesoybeancropsbetween thetwoseasons, except forthe temperature(Table 1). The averagerainfall, humidity,andsolar radiationofthe firstseasonwere higherthan thesecondseason.

This is becausein thesecondseason, was peak of the dryseason, especially in Bogor.

Table 1.Climatic data from Bogor District in 2014.

Season	Month	Rainfall (mm)	Temperature (°C)	Relative humidity	Solar radiation (%)
Season 1	March	689	25.6	87.0	51.0
	April	677	26.0	85.0	72.0
	May	598	26.0	85.0	71.0
	Mean	655	25.9	85.7	64.7
Season 2	July	349	25.8	83.0	70.2
	August	538	25.7	80.0	91.1
	September	43	28.5	73.0	95.1
	Mean	310	25.8	78.7	80.7

Source: The Agency for Meteorology, Climatology, Geophysic, Bogor (BMKG, 2014).

Effect of genotype, season, and genotype x season interaction to agronomic traits of soybean lines

Thecombinedanalysis of varianceshowedthatthe seasonsignificantly affectedsomeagronomiccharacterssuch as the numberofnodes, the number of branches, number of totalpods,days to flowering, days to harvesting, weight of 100seeds,andproductivity(Table 2). This indicatedthat theprom-ising lineswere strongly influencedbyseasonal changescaused bydifferences intherainfall(Table 1). Plant heightandnumber of podsperplantwere notaffectedby the seasons.

Table3 aboveshowedthatin the firstseason, the agronomic characterssuch as the numberof branches, the number ofnodes, 100-seed weight, seed weightperplantand yield potential have higher valuesthansecondseason,except for thenumber of totalpods(Table3). This indicatedthatthecharacteris strongly influencedbythe changing seasons. In thefirstseasonthe rainfall ishigher thanin thesecondseasonso that thewaterin thesecondseasonwas notsufficientforthe growthanddevelopment of soybean. Lack of waterduringthe floweringphaseresults ina reduced number ofpods(Desclaux*et al.*, 2000),the number of seedsperpod(Adie, 1992)and seed size(Fattah *et al.*, 2005). Drought stressinhibitscarbohydratesdistributionfromleavestop odsso thatthe numberandsize ofseedsdecreased(Liu *et al.*, 2004). Dogan*et al.*(2007) reported thatdrought stressduringphasephaseR3, R5andR6lowering the yield33%, 31% and50%, respectively.

The results ofthe combinedanalysis of varianceshowedthatgenotypesignificantly affectedplant heighton averagefor thesecondseason. Plant heightwas highestin lineSC-54-1 which wassignificantly higherthanallthreelinesandthe check varieties.

The lineCG-22-10, SC-1-8, SC-56-3 andSP-30-4 haveplant heightwerenotdifferent from the threecheck varietiesSibayak, TanggamusandWillis(Table 4).

Table 2.Combined analysis of two seasons for agronomic characters of soybean lines.

Agronomic Characters	Mean square			
	Season (S)	Genotype (G)	S x G	cv (%)
Plant height	0.05ns	8.35**	1.71	7.61
Number of branches	52.84**	4.30**	4.30**	13.37
Number of nodes	6.50*	3.35**	3.12**	12.15
Number of filledpods	6.50	3.35	3.12	19.12
Number of total pods	12.24**	2.34*	1.83	17.09
Days to flowering	32.22**	14.00**	0.55	2.01
Days to harvesting	94.70**	34.70**	3.83**	0.34
Seed weight per plant	37.60**	1.91	1.88	20.32
Weight of 100 seeds	44.55**	12.06**	0.88	11.19
Productivity	133.58**	1.48	1.95	17.59

Note: * = significant at 5%; ** = significant at 1%.

Table 3.Agronomic traits performance of lines evaluated in the season 1 and season 2.

Agronomic characters	Season 1 (S1)		Season 2 (S2)		Average
Plant height (cm)	79.1	a	78.8	a	78.9
Number of branches	4.8.0	a	3.7	b	4.3
Number of nodes	27.4	a	25.3	b	26.4
Number of filled pods	63.3	b	73.9	a	68.6
Number of total pods	60.0	a	63.4	a	61.7
Days to flowering(das)	85.9	a	85.2	b	85.5
Days to harvesting(das)	8.2	a	6.7	b	7.4
Seed weight per plant (g)	36.8	a	35.7	b	36.3
Weight of 100 seeds (g)	9.7	a	7.0	b	8.4
Productivity(tons/ha)	3.0	a	1.8	b	2.4

Note: numberfollowed bythe sameletterin the same roware not significantly differentat5% DMRT; das=days after sowing.

Table 4.The effect of genotype against plant height, number of branches, number of nodes, number of filled pods, and number of total pods.

Genotype	Plantheight(cm)		Number of branches		Number of nodes		Number of filled pods	Number of total pods	
CG-22-10	79.95	bcd	5.0	a	29.9	a	70.1	80.6	a
PG-57-1	84.45	b	4.7	ab	29.2	a	66.6	73.9	abc
SC-1-8	76.10	cde	4.6	ab	26.4	abc	55.5	61.8	bc
SC-21-5	83.15	bc	4.6	ab	27.3	ab	64.0	73.5	abc
SC-54-1	94.10	a	4.2	bc	27.4	ab	64.3	71.4	abc
SC-56-3	80.10	bcd	4.7	ab	25.8	abc	68.5	75.5	ab

SP-30-4	69.95	e	3.8	cd	22.7	c	52.2	58.4	c
Sibayak	74.85	ed	4.1	bc	27.2	ab	57.7	64.3	bc
Tanggamus	72.45	ed	3.4	d	22.9	c	60.0	64.8	bc
Wilis	74.10	ed	3.8	cd	24.8	bc	58.3	61.7	bc

Note: numberfollowed bythe sameletterin the same roware not significantly differentat5% DMRT.

Genotypesignificantly affected thenumber ofbranchesandthe number of node. The number ofbranchesin linesCG-22-10 was notsignificantly different from thelinesPG-57-1, SC-1-8, SC-21-5 andSC-56-3, butthefivelineshave therealnumber oflargerbranchescompared to the twovarietiesTanggamusandWilis. Lines SC-54-1 andSP-30-4 have thesamenumber ofbrancheswith avarietySibayakandWilis(Table 4).

CG-22-10, PG-57-1, SC-1-8, SC-21-5, SC-54-1,SC-56-3,andSibayakhave similarnumber of nodes.BothlinesCG-22-10 andPG-57-1 have therealnumber of productive nodesmorethan theSP-30-4 lineandvarietiesTanggamusandWilis.

Table4showedthat thegenotypesignificantly affected thetotalnumber of pods. Highesttotalnumber of podswas found in lineCG-22-10 whichwas notsignificantly different fromlinesPG-57-1, SC-21-5, SC-54-1 andSC-56-3, but thelinesCG-22-10significantly largerthan thelineSC-1-8 andSP-30-4 andcheckvarietiesSibayak, Tanggamus and Wilis.

The analysis showedthat of significant effects of genotypesondays to flowering(Table 5). The longest days to flowering wasinthe line SP-30-4 which was not different fromTanggamusvarieties, butwas significantlylongerthanallother linesandbothcheck varietiesSibayakandWilis.The lineSC-1-8 has shorter dayas tofloweringthanlineCG-22-10, PG-57-1, SC-21-5, SC-56-3 andSP-30-4 andbothvarietiesTanggamusandWillis, butwas not much differentfrom thelineSC-54-1 and the checkvarietiesSibayak. Yunita*et al.*(2009) reportedthat thelinesSC-1-8, SC-54-1 andSC-56-3 haveshorter days to floweringthan that of Sibayak.

Genotypesignificantly affected days toharvesting. The mean in thesecondharvestseasonshowedthatthe days to harvesting of linesCG-22-10, PG-57-1, SC-1-8, SC-21-5, SP-30-4 are similar with Wilisvarieties. The lineSC-54-1 hasshorter days to harvestingthanallthreecheck varietiesfollowedby lineSC-56-3 (Table 5). The shorterdays to harvesting of lineSC-54-1 was due to shorter days to flowering. Tanggamusvarietyhaslongerdays to harvestingofalllinesand theothertwocheck varieties.

Seed sizeis onecharacterthatcanincrease theproductivity of soybean. The analysis showedthe influence ofgenotypeson theweight of100 seeds, where thelineSC-1-8 andSP-30-4 have seedsizelarger than the other lines, but wasnot differentwith the threecheck varieties(Table 5). Consumersgenerally preferlarge seedsthatincreasethe size of theseedthroughthe selectionshould bedone simultaneouslyimproveoutcomes(Soepandi*et al.*, 2006). Ojo*et al.*(2012) reportedthat thecharacternumber of podsper plantand100-seed weighthave greatercontributionthanother agronomiccharactersto the yield of soybeanlinestested. The results oftwoseasonscombinedanalysis of varianceshowedthatgenotypedid not significantly affectweightperplantandyield potential. Thismeansthatalllineshave theweightperplantandyield potential similar to the check varieties.

Plant heightwas notaffectedbythe interaction ofgenotypex season. This suggeststhatthe responseof allgenotypesto different climatic conditions of the two seasonsis the same, wherethere is nogenotypethat is sensitive tothe change of seasons(Table 6).

Table 5. The effect of genotype against days to flowering, days to harvesting, weight of 100 seeds, seeds weight per plant, and productivity.

Genotype	Days to flowering (das)		Days to harvesting(das)		Weight of 100 seeds (g)		Seeds weight per plant (g)	Productivity (tons/ha)
CG-22-10	36.8	b	85.5	bc	6.1	b	8.0	2.6
PG-57-1	36.7	b	85.5	bc	6.3	b	7.9	2.4
SC-1-8	34.7	d	85.5	bc	8.8	a	10.8	2.8
SC-21-5	36.7	b	85.5	bc	6.2	b	8.0	2.6
SC-54-1	35.0	cd	84.7	e	7.1	b	8.1	2.6
SC-56-3	35.7	c	85.0	de	6.2	b	7.7	2.5
SP-30-4	38.0	a	85.5	bc	8.2	a	7.6	1.9
Sibayak	35.0	cd	85.7	b	8.8	a	9.3	2.3
Tanggamus	37.2	ab	87.3	a	8.4	a	8.5	2.4
Wilis	37.0	b	85.2	cd	8.6	a	8.2	2.6

Note: Note: numberfollowed bythe sameletterin the same roware not significantly differentat5% DMRT.

Table 6.The effect of interaction against number of branches, number of nodes, and days to harvesting.

Genotype	Number of nodes				Number of branches				Days to harvesting (das)			
	S1		S1		S1		S2		S1		S2	
CG-22-10	29.3	ab	30.6	a	5.4	ab	5.4	ab	86	c	85	d
PG-57-1	33.4	a	25.0	c	5.5	a	5.5	a	86	c	85	d
SC-1-8	30.0	ab	22.9	c	6.1	a	6.1	a	86	c	85	d
SC-21-5	28.2	abc	26.4	bc	5.2	ab	5.2	ab	86	c	85	d
SC-54-1	25.6	c	29.3	ab	4.0	cde	4.0	cde	85	e	85	e
SC-56-3	27.5	abc	24.0	c	5.5	a	5.5	a	85	d	85	d
SP-30-4	22.0	c	23.4	c	3.9	de	3.9	de	86	c	85	d
Sibayak	31.6	a	22.8	c	4.9	b	4.9	b	86	c	85	d
Tanggamus	22.9	c	22.9	c	3.7	def	3.7	def	88	a	87	b
Wilis	23.6	c	25.9	c	3.9	de	3.9	de	85	d	85	d

Note: numberfollowed bythe sameletterin the same row and the same columnare not significantly differentat5% DMRT.

Table6showedthatthe effect ofthe interactionbetweengenotype x seasonto thenumber ofbranches. The effect ofthisinteractionshowed thatgenotyperesponsedifferently tothe change of seasons, where thefirstseasonthe averagerainfall washigher thanthe secondseason(Table 1), so that thevegetativegrowthin thefirstseasonwas better thanthe secondseason. During the firstseasonalmostalllineshavethe samenumber of brancheswith checkvarietySibayak,exceptlinesSC-54-1 andSP-30-4. However, lineSC-1-8 has anumber ofbrancheswhichwere significantly higher thanthe threecheck varietiesSibayak, TanggamusandWilis. In the second, thelineCG-22-10 andSC-54-1 have thenumber ofbranchesthatwere not significantly different fromWilisvarietiesbutwere significantly higher than bothcheck varietiesSibayakandTanggamus.

Theresults ofthe combinedanalysis of varianceshowedthatthe interactionbetweengenotypexseason affectedthenumber ofnodes. In the firstseasonlinePG-57-1 have theprolificnumberof nodesthatwere not different fromotherlinessuch asCG-22-10, SC-1-8, SC-21-5, SC-56-3 andthe check varietySibayak, butmarkedly higher than thatofth two linesSC-54-1 andSP-30-4 andvarietiesTanggamusandWillis(Table 6). In the secondseason,thelinesPG-57-1, nearlyallthe lineshave thenumberof nodesthat were notsignificantly different fromthe threecheck varieties. The lineCG-22-10 have thenumber ofbranchesthatwere significantly higher thanthe threevarietiesand followedby lineSC-54-1 which ws not differentvarieties ofWilis, but significantly higher thanthe twovarietiesSibayakandTanggamus.

Table7showed,thatthere is nointeraction effectbetweengenotypeandseasononthe characters ofnumber of pods, number of podsanddays to flowering. The absence ofinteractionshowsthatthe responseof allgenotypesin the different seasons were the same for the characters.

Days to harvesting is significantly influencedby seasons. This isdue to the interactionbetweengenotypeandseasonthat resulted inthe responseto thechanging seasonsdiversegenotypes. In the firstseason,thelineSC-54-1 has theshortest days to harvestcompared toall thelines and checkvarieties,butwere not significantly differentin thesecondseason. The days to harvest in the firstseasonshowed that there were5linesand1checkvariety,namelyCG-22-10, PG-57-1, SC-1-8, SC-21-5, SP-30-4 andvarietiesSibayakthat have the same days to harvest(Table 7). The5genotypeshave thedifferentdays to harvestin thesecondseasonthan the firstseason. All genotypes have the same days to harvestinginthe secondseasonincluding the checkvarietiesSibayakandWilis,except forTanggamusvariety. The uniformdays to harvest of allthesoybean promising linein thesecondseasonwascausedbydroughtwhichcausedall thepodsto dryand cracked.

The analysis showedthatthere is a lack of effectof theinteraction ofgenotype× seasonon seed weightperplant, weight of 100g seedsandproductivity(Table 8). Thismeansthatallgenotypesresponseto changes intheseasonwerestable.Adaptationabilitycausedbya combination of propertieswhichcancope with environmental changeso thatthe genotypeis notaffected by the change ofseasons(Cucolotto*et al.*, 2006). Djaelani*et al.*(2001) revealedthatifthe absence ofinteraction, the selection ofthe bestgenotypeswouldbe easier, that is byselectinggenotypes that have the highest yield average. Generally, farmers are more interestedin varietiesfeaturingconsistent results over seasons (Tarakan-ovasandRuzgas,2006).

Table 7.Performance of genotypes evaluated in different season.

Genotype	Plantheight(cm)		Number of filled pods		Number of total pods		Days to flowering (das)	
	S1	S2	S1	S2	S1	S2	S1	S2
CG-22-10	79.2	80.7	70.4	69.7	73.7	87.5	37.3	36.3
PG-57-1	80.7	88.2	71.0	62.2	74.5	73.3	37.3	36.0
SC-1-8	71.3	80.9	54.0	57.1	57.7	65.9	35.3	34.0
SC-21-5	83.3	83.0	63.5	64.5	67.6	79.4	37.7	35.7
SC-54-1	99.0	89.2	54.9	73.6	57.4	85.3	35.3	34.7
SC-56-3	79.8	80.4	73.7	63.3	78.1	72.9	36.0	35.3
SP-30-4	70.6	69.3	44.0	60.5	47.1	69.7	38.3	37.7
Sibayak	75.6	74.1	65.7	49.7	69. 7	58.9	35.3	34.7
Tanggamus	77.9	67.0	55.4	64.5	57. 7	72.1	37.7	36.7
Wilis	73.5	74.7	47.9	68.8	49.7	73.8	37.7	36.3

Table 8. Performance of seed weight per plant, weight of 100 seeds andproductivity of each genotype in different season.

Genotype	Seed weight per plant(g)		Weight of 100 seeds (g)		Productivity(tons/ha)	
	S 1	S 2	S 1	S 2	S 1	S 2
CG-22-10	9.4	6.5	6.7	5.4	3.4	1.7
PG-57-1	9.8	6.0	6.9	5.7	3.3	1.5
SC-1-8	11.3	10.3	9.1	8.5	3.1	2.5
SC-21-5	9.3	6.7	7.3	5.1	3.4	1.8
SC-54-1	8.7	7.4	8.2	5.9	3.3	1.9
SC-56-3	9.8	5.6	6.6	5.8	3.4	1.5
SP-30-4	8.3	6.8	8.8	7.5	2.4	1.3
Sibayak	12.7	5.8	9.9	7.6	2.7	1.8
Tanggamus	9.5	7.5	8.9	7.8	2.8	1.9
Wilis	8.5	7.9	9.1	8.0	2.9	2.2

Conclusion

There is the effect ofinteraction ofgenotype×season on the performance of the agronomic characters of numberof productive nodes, the number ofproductivebranchesanddays to harvest. The yield potential of the soybean lines was higher in the first seasonthanthe secondseason, at3.1ton/haand1.8ton/ha, respectively.The lineCG-22-10, PG-57-1, SC-21-5, SC-54-1 andSC-56-3 have yield potential higher than the meanacrossgenotypesin thefirstseason.

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