Biotechnology in Animal Husbandry 31 (1), p 133-143 , 2015 ISSN 1450-9156
Publisher: Institute for Animal Husbandry, Belgrade-Zemun UDC 631.816'633.853.52
DOI: 10.2298/ BAH1501133M

EFFECT OF FOLIAR FERTILIZATION ON SOYBEAN GRAIN YIELD

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Original scientific paper

Abstract: The aim of this investigation was to estimate the effects of foliar fertilization on quantitative traits (plant height, first pod height, number of nodes per plant, number of pods per plant, number of grain per plant, grain yield per plant, 1000-grain weight and grain yield) in two soybean cultivars (Balkan and Bečejka). Studied cultivars belong to different maturity groups (Balkan - I and Bečejka - 0). Four treatments of fertilization were tested: control (no fertilization), Urea (46 kg N ha^{-1}), Urea (46 kg N ha^{-1}) + Wuxal super (5 l ha^{-1}) and Urea (46 kg N ha^{-1}) + Ferticare I (5 kg ha^{-1}). Wuxal super and Ferticare I were foliar applied two times at the R2-R3 growth stage. The field experiments were carried out in dry land farming in the region of Vojvodina province at location Putinci (45° 00′ N Lat., 19° 58′ E Long.), during the years 2007 and 2008. In both research years, Balkan had higher values for all investigated traits than Bečejka. Results showed that foliar fertilizers significantly increased the values for all quantitative traits. Ferticare I is more effective than Wuxal super in soybean because this fertilizer has higher concentration of macronutrients. Foliar fertilization of soybean reduced the negative impact of small amounts of rainfall during the summer months on grain yield.

Key words: cultivar, foliar fertilization, soybean, qvantitative traits

Introduction

Soybean is the most important legume in Serbia of animal feed and food production. Soybean seeds to make high protein meal which is used largely as a supplement to cereal seeds in feed domesticated livestock such as dairy cows, cattle, pigs, goats, sheep, horses and poultry *(Iqbal et al., 2003; Ranđelović, 2009)*. *Marinković et al. (2010)* reported that nitrogen deficiency in the soil results in significant yield losses and yield quality reduction of soybean. Results by *Starling et al. (2000)* showed that plant growth and grain yield of soybean were higher

when fertilizer nitrogen was applied as starter. Many researchers indicate the importance of foliar feeding of soybean plants. Foliar feeding is the practice of applying liquid fertilizers to plant leaves *(Kovačević, 2003). Silberbush (2002)* reported that foliar fertilization is widely used practice to correct nutritional deficiencies in plants caused by improper supply of nutrients to roots. *Ranđelović (2009)* reported that the uptake of mineral nutrients from the soil and the extent of their utilization by the soybean plant depend on weather conditions during the growing season. In this case, preference should be given to the application of foliar fertilizers. *Camberato et al. (2010)* reported that if the micronutrient deficiencies do occur during the growing season, the most effective method for overcoming these deficiencies is through foliar fertilizer applications. *Rehm et al. (1997)* concluded that foliar fertilization is not a substitute for a program based on soil-applied fertilizers. They suggest that applications of phosphate and potash before planting are the most reliable method for meeting soybean material needs. *Barge (2001)* found that the foliar fertilizers (ElamMax (27% Mn), Folizyme (12% N, 3% K, 3% Ca and 3% Mn), Keylate (5% Mn), White Label (6% Mn) and Harvest More Urea Mate (N, P, K, Ca, Mg, B, Co, Cu, Mn, Mo and Zn) increased grain yield of soybean than control. *Mallarino et al. (2005)* reported that the foliar fertilization at early vegetative stages of soybean increased grain yield in 15 to 30% of the fields depending on the year. *Ashour and Thalooth (1983)* studied the effect of soil-fertilized with 35, 70 or 105 kg N ha^{-1} or foliar-sprayed with 0.5 or 1.0% urea at the R6 stage of plants development of soybean cv. Clark. Their results showed that foliar application of 1.0% urea the most increased fruit-set, weight of pods, and the yield of oil and protein in seed. *Garcia and Hanway (1976)* evaluated various nutrient combinations for foliar application at the R2 to R7 growth stages and found that a 10-1-3-0.5 N-P-K-S ratio increased yields by 441 to 504 kg ha^{-1}. They concluded that the optimum time of foliar application was between growth stages R5 and R6. *Haq and Mallarino (2000)* showed that N–P–K foliar fertilization of relatively small amounts sprayed at the V5 stage affected yields significantly at 6 or 27 sites. However, researches by *Schmitt et al. (2001)* and *Binford et al. (2004)* reported that foliar applications of N-P-K show decreases or no significant soybean grain yield differences. *Kaiser et al. (2007)* found that foliar fertilization with two fluid 3-8-15 and 28-0-0 (N-P-K) fertilizers at V5 or R2 growth stages, did not affect the grain yield of soybean cultivars.

The aim of this investigation was to the effects of soil and foliar fertilization on agronomic traits and grain yield in two soybean cultivars and to determine better foliar fertilizer and genotype in agro-climatic condition of Srem.

Materials and Methods

The experiments were carried out in dry land farming in the region of Srem, localitety Putinci (45° 00′ N Lat., 19° 58′ E Long.), on the calcareous chernozem soil of the loess terrace, during years 2007 and 2008. The main

characteristics of the soil (depth: 0-50 cm) were: pH in KCl – 6.1; pH u H_2O – 7.2; $CaCO_3$ – 7.2% (carbonate); humus – 2.01, total N – 0.11%. The soil contained 11.9 and 20.1 mg/100g soil phosphorus and potassium, respectively. Two soybean cultivars Balkan (maturity group I) and Bečejka (maturity group 0) were used as material. Plots were organized as a randomized block system design in four replications.

Meteorological conditions have a major impact on plant growth *(Popović et al., 2013a, Ikanović et al., 2014)*. Weather conditions had varying between 2007 and 2008 year, especially true of the amount and distribution of rainfall (Table 1). In 2007, average annual rainfall (358.8 mm) was higher 45.5 mm (14.5%) than in 2008 (313.3 mm). In both year researches monthly air temperatures was higher than long-term monthly air temperatures.

Table 1. Mean monthly air temperatures and sum of rainfall

Months	Temperature (^oC)			Rainfall (mm)		
Year	2007	2008	1981-2010	2007	2008	1981-2010
X - III	-	-	-	254.6	260.4	260.5
IV	13.0	12.9	11,8	0	52.4	48.4
V	18.5	18.3	17,2	79.0	42.4	56.2
VI	22.0	21.7	19.9	85.2	58.1	84.4
VII	22.6	21.7	21.5	38.7	61.0	61.6
VIII	22.3	21.5	21.2	62.5	22.7	52.8
IX	14.3	15.4	16.6	93.4	76.7	50.3
Mean	18.8	18.6	18.0	-	-	-
Growing season	-	-	-	358.8	313.3	353.7
Annual	-	-	-	613.4	573.7	614.2

Four treatments of fertilization were tested: control, Urea, Urea + Wuxal super and Urea + Ferticare I. The Urea (46 kg N ha^{-1}) was incorporated into the soil before sowing. Foliar fertilizers Wuxal super (5 l ha^{-1}) and Ferticare I (5 kg ha^{-1}) were applied two times at 10 days interval at the R2-R3 growth stages. Foliar fertilizers contain microelements in the form of chelate complexes, which ensures high utilization and good mobility of adopted elements. Wuxal super is a liquid fertilizer that contains macronutrients (8% N, 8% P_2O_5, and 6% K_2O) and micronutrients (0.01% B, 0.015% Fe, 0.007% Cu, 0.013% Mn, 0.001% Mo, and 0.005% Zn). Ferticare I is a crystal fertilizer that contains macronutrients (14% N, 11% P_2O_5, 25% K_2O, and 2.3% MgO) and micronutrients (0.02% B, 0.01% Cu, 0.1% Fe, 0.1% Mn, 0.002% Mo, and 0.01% Zn). Preceding crop was winter wheat. Soybean planting was done on April 12 in 2007 and April 16 in 2008. The plant densities were used 450000 plants ha^{-1} (Balkan) and 500000 plants ha^{-1} (Bečejka). Plot size was $10m^2$ (5 m x 2 m), and the row-to-row spacing was 50 cm. Plots were rolled after sowing. A standard cultivation practice was applied.

Soybean harvest was performed manually. Ten plants randomly selected from each plot were used to record data seven quantitative traits (plant height, first pod height, number of nodes per plant, number of pods per plant, number of grain

per plant, grain yield per plant and 1000-seed weight). After harvesting grain yield was converted into t ha^{-1}. Grain yield is calculated on a 13% moisture basis.

Data were processed using analysis of variance (ANOVA) according to a linear model which included effects of cultivar and fertilizer treatments, and the interaction between them. The statistical tests were carried out using STATISTICA (version 10; StatSoft, Tulsa, Oklahoma, USA). The significance level was set at $P \leq 0.05$ and $P \leq 0.01$. Differences between traits means were assessed using Duncan's Multiple Range Test at $P \leq 0.05$ level.

Results and Discussion

Results showed that soybean cultivar Balkan, in average for years and fertilizer treatments, produced higher plant height (108.8 cm), first pod height (12.3 cm), number of nodes per plant (13,0), number of pods per plant (56.4), number of grain per plant (121.0), grain yield per plant (20.76 g), 1000-grain weight (181.89 g) and grain yield (3950 kg ha^{-1}) than cultivar Bečejka (92.6 cm, 10.6 cm, 11,3, 48.8, 104.0, 18,04 g, 169.48 g and 3347 kg ha^{-1} respectively), Table 2, 3 and 4.

Table 2. Effect of different fertilizer treatments on plant height (cm), first pod height (cm) and number of nodes per plant of soybean cultivars

Year	Fertilizer (B)	Traits								
		Plant height			First pod height			No of nodes per plant		
		Cultivar (A)								
		Balkan	Bečejka	M	Balkan	Bečejka	M	Balkan	Bečejka	M
2007	Control	112.4	95.1	103.8^{d}	11.8	9.3	10.6^{c}	13.5	10.5	12.0^{c}
	Urea	127.1	104.1	115.6^{c}	12.9	10.1	11.5^{b}	14.9	12.5	13.7^{b}
	Urea+Wuxal	136.7	104.5	120.6^{b}	14.0	10.1	12.1^{ab}	15.2	12.7	14.0^{b}
	Urea+Ferticare I	139.7	107.4	123.6^{a}	14.2	11.0	12.6^{a}	15.6	13.3	14.4^{a}
	M	129.0^{a}	102.8^{b}	115.9	13.2^{a}	10.1^{b}	11.7	14.8^{a}	12.2^{b}	13.5
F test		A	B	AxB	A	B	AxB	A	B	AxB
		**	**	**	**	**	ns	**	**	ns
2008	Control	83.9	67.0	75.4^{d}	10.5	10.6	10.6^{d}	9.3	8.3	8.8^{c}
	Urea	88.2	83.2	85.7^{c}	11.0	10.8	10.9^{c}	11.1	10.1	10.6^{b}
	Urea+Wuxal	90.5	85.7	88.1^{b}	11.2	11.1	11.2^{b}	12.2	11.5	11.9^{a}
	Urea+Ferticare I	91.3	93.9	92.6^{a}	12.6	12.0	12.3^{a}	12.5	11.6	12.1^{a}
	M	88.5^{a}	82.4^{b}	85.4	11.3^{a}	11.1^{a}	11.2	11.3^{a}	10.4^{b}	10.9
F test		A	B	AxB	A	B	AxB	A	B	AxB
		**	**	**	ns	**	ns	**	**	ns
M	Control	98.2	81.0	89.6	11.2	10.0	10.6	11.4	9.4	10.4
	Urea	107.7	93.7	100.7	12.0	10.4	11.2	13.0	11.3	12.2
	Urea+Wuxal	113.6	95.1	104.4	12.6	10.6	11.7	13.7	12.1	13.0
	Urea+Ferticare I	115.5	100.7	108.1	13.4	11.5	12.4	14.1	12.4	13.2
	M	108.8	92.6	100.7	12.3	10.6	11.5	13.0	11.3	12.2

Mean followed by different letters are significantly different by Duncan's Multiple Range Test at $p \leq 0.05$; ns - not significant; * - significant at $P \leq 0.05$; ** - significant at $P \leq 0.01$

In both research years, cultivar Balkan had higher values for all investigated traits compared to cultivar Bečejka. These differences were statistically significant, except for first pod height in 2008. The higher values for all quantitative traits in 2007 can explain the favorable distribution of rainfall than 2008. In our production conditions is a critical stage of grain filling (August) when lack of rainfall leads to a decrease in soybean grain yield. In 2008 drought stress was in August.

Results showed that treatment fertilizer Urea + Ferticare I, in average for years and cultivars, produced highest plant height (108.1 cm), first pod height (12.4 cm), number of nodes per plant (13.2), number of pods per plant (58.1), number of grain per plant (124.8), grain yield per plant (21.46 g ha^{-1}), 1000-grain weight (185.84 g) and grain yield (3961 kg ha^{-1}). Values of these traits were higher in 2007 (favorable weather conditions) than in 2008.

Table 3. Effect of different fertilizer treatments on number of pods per plant, number of grain per plant and grain yield per plant (g) of soybean cultivars

Year	Fertilizer (B)	Traits								
		No of pods per plant			No of grain per plant			Grain yield per plant		
		Cultivar (A)								
		Balkan	Bečejka	M	Balkan	Bečejka	M	Balkan	Bečejka	M
2007	Control	56.7	46.8	51.8^{d}	122.7	98.8	110.8^{d}	20.98	17.30	19.14^{d}
	Urea	63.1	53.5	58.3^{c}	135.7	115.0	125.4^{c}	23.20	20.24	21.72^{c}
	Urea+Wuxal	66.4	55.9	61.2^{b}	142.8	120.2	131.5^{b}	24.75	21.64	23.20^{b}
	Urea+Ferticare I	68.7	58.5	63.6^{a}	148.4	126.3	137.4^{a}	26.12	21.35	23.74^{a}
	M	63.7^{a}	53.7^{b}	58.7	137.4^{a}	115.1^{b}	126.3	23.76^{a}	20.13^{b}	21.95
F test		A	B	AxB	A	B	AxB	A	B	AxB
		**	**	ns	**	**	**	**	**	**
2008	Control	41.0	36.5	38.8^{c}	86.5	75.8	81.2^{d}	14.62	13.74	13.68^{d}
	Urea	45.8	41.1	43.4^{b}	97.1	87.3	92.2^{c}	16.31	15.21	15.76^{c}
	Urea+Wuxal	53.7	48.0	50.9^{a}	116.0	103.0	109.5^{b}	19.80	17.74	18.77^{b}
	Urea+Ferticare I	55.6	49.5	52.6^{a}	118.5	105.9	112.2^{a}	20.30	18.06	19.18^{a}
	M	49.0^{a}	43.8^{b}	46.4	104.5^{a}	93.0^{b}	98.8	17.76^{a}	15.94^{b}	16.85
F test		A	B	AxB	A	B	AxB	A	B	AxB
		**	**	ns	**	**	ns	**	**	**
M	Control	48.9	41.7	45.3	104.6	87.3	96.0	17.80	15.02	16.41
	Urea	54.4	47.3	50.9	116.4	101.2	108.8	19.76	17.72	18.74
	Urea+Wuxal	60.0	52.0	56.0	129.4	111.6	120.5	22.28	19.69	20.99
	Urea+Ferticare I	62.2	54.0	58.1	133.4	116.1	124.8	23.21	19.71	21.46
	M	56.4	48.8	52.6	121.0	104.0	112.5	20.76	18.04	19.40

Mean followed by different letters are significantly different by Duncan's Multiple Range Test at $p \leq 0.05$; ns - not significant; * - significant at $P \leq 0.05$; ** - significant at $P \leq 0.01$

In both years fertilizer treatments were significantly increased all studied quantitative traits, especially with the foliar treatment. In 2007 the minimum traits values observed in control (plant height 103.8 cm, first pod height 10.6 cm, number of nodes per plant 12.0, number of pods per plant 51.8, number of grain per plant

110.8, grain yield per plant 19.14 g, 1000-grain weight 164.22 g and grain yield 3624 kg ha^{-1}) and maximum in treatment Urea + Ferticare I (123.6 cm, 12.6 cm, 14.4, 63.6, 137.4, 23.74 g, 191.90 g and 4366 kg ha^{-1}, respectively). Also, in 2008 the minimum traits values observed in control (plant height 75.4 cm, first pod height 10.6 cm, number of nodes per plant 8.8, number of pods per plant 38.8, number of grain per plant 81.2, grain yield per plant 13.68 g, 1000-grain weight 156.67 g and grain yield 2919 kg ha^{-1}). The maximum traits values observed in treatment Urea + Ferticare I (plant height 92.6 cm, first pod height 12.3 cm, number of nodes per plant 12.1 number of pods per plant 52.6, number of grain per plant 112.2, grain yield per plant 19.18 g and grain yield 3555 kg ha^{-1}) except 1000-grain weight which highest in treatment Urea + Wuxal super (181.38 g). Our research has showed that foliar feeding should be given priority under conditions of limited uptake of nutrients from the soil. Values of all traits were higher in treatments with foliar fertilization than in control and treatment Urea.

Many researchers have reported that foliar fertilization treatments significantly increase plant height *(Prijić et al., 2003; Ranđelović, 2009; El-Abady et al., 2008; Yildirim et al., 2008; Popović et al., 2013b)*, first pod height *(Ranđelović, 2009)*, number of nodes per plant *(Odeleye et al., 2007; Ranđelović, 2009)*, number of pods per plant *(Schon and Blevins, 1990; Reinbott and Blevins, 1995; El-Abady et al., 2008; Yildirim et al., 2008; Ranđelović, 2009)*, number of grain per plant *(Odeleye et al., 2007; El-Abady et al., 2008; Ranđelović, 2009)*, grain yield per plant *(Schon and Blevins, 1990; El-Abady et al., 2008; Ranđelović, 2009)* and 1000-grain weight *(Ranđelović, 2009; Popović et al., 2013b)*. Contrary, *Abdel-Gawad et al. (1989)* and *Yildirim et al. (2008)* reported that foliar fertilization did not have any statistical effect on 1000-grain weight. Foliar fertilization of soybean at early vegetative stages increased soybean grain yield in approximately 15% *(Haq and Mallarino, 2000; Mallarino et al., 2001)*. *Garcia and Hanway (1976)* found that yield of soybean increases of 27 to 31% when a foliar fertilizer (N, P, K, S) was applied at late reproductive stages. *Woon and Porter (1986)* reported that foliar fertilizers (FF) applied at the reproductive growth stage increased soybean yield but FF formulations 16N + 4P + 4K + 1 S gives higher yield than formulation 12 N + 4 P + 4 K + 0.5 S. *Peele (1997)* reported that the foliar dressing of macronutrients increased soybean grain yield by 30 to 400 kg ha^{-1}. *Oko et al. (2003)* reported that the foliar fertilization of urea at the R2-R3 growth stage increased soybean grain yield between 6 and 68% compared to control. *Ranđelović et al. (2009)* reported that method of foliar feeding has been proved as an effective tool for increasing of grain yield in two soybean cultivars with reduced content of Kunitz trypsin inhibitor (Laura and Lana). *Sultan et al. (2003)* reported that spraying with foliar fertilizers at 45 days after sowing increased grain yield of soybean. *Haq and Mallarino (2005)* found that foliar N fertilization increased protein and oil production because of soybean yield increases. *Popović et al. (2013c)* reported that NS soybean varieties Galina

(maturity group 0), Victoria and Tea (maturity group I) had higher yield and 1000-grain weight in the variant with foliar fertilization with fitofert (composition: 12% N, 4% P_2O_5, 6% K_2O, 0.013% Mn, 0.010% Fe, 0.008% B, 0.006% Cu, and 0.005% Zn) than in the control. Contrary, earlier research *Parker and Boswell (1980)* reported a 10.9% and 17.6% soybean grain yield decrease with application of foliar fertilizers. *Chowdhury et al. (1985)* obtained that the high level of foliar fertilization did not significantly effect on the grain yield in soybean cultivars Williams and Micthel.

Table 4. Effect of different fertilizer treatments on 1000-grain weight (g) and grain yield (kg ha^{-1}) of soybean cultivars

Year	Fertilizer treatments (B)	Traits					
		1000-grain weight			Grain yield		
		Cultivar (A)					
		Balkan	Bečejka	M	Balkan	Bečejka	M
2007	Control	171.39	157.04	164.22^{d}	3889	3358	3624^{b}
	Urea	184.96	165.85	175.40^{c}	4679	3544	4112^{a}
	Urea+Wuxal	198.22	173.82	186.02^{b}	4698	3722	4210^{a}
	Urea+Ferticare I	203.02	180.77	191.90^{a}	4793	3939	4366^{a}
	M	189.40^{a}	169.37^{b}	179.39	4515^{a}	3641^{b}	4078
F test		A	B	AxB	A	B	AxB
		**	**	**	**	**	ns
2008	Control	157.42	155.91	156.67^{c}	3096	2742	2919^{d}
	Urea	171.08	167.10	169.09^{b}	3198	2991	3095^{c}
	Urea+Wuxal	182.89	179.86	181.38^{a}	3458	3159	3309^{b}
	Urea+Ferticare I	184.14	175.44	179.79^{a}	3792	3318	3555^{a}
	M	173.88^{a}	169.58^{b}	171.73	3386^{a}	3053^{b}	3220
F test		A	B	AxB	A	B	AxB
		**	**	*	**	**	ns
M	Control	164.40	156.48	160.44	3493	3050	3272
	Urea	178.02	166.48	172.25	3939	3268	3604
	Urea+Wuxal	190.56	176.84	183.70	4078	3441	3760
	Urea+Ferticare I	193.58	178.10	185.84	4292	3629	3961
	M	181.89	169.48	175.56	3950	3347	3649

Mean followed by different letters are significantly different by Duncan's Multiple Range Test at $p \leq 0.05$; ns - not significant; * - significant at $P \leq 0.05$; ** - significant at $P \leq 0.01$

The interaction of soybean cultivars and fertilizer treatments did not significantly affect the first pod height, number of nodes per plant, number of pods per plant and grain yield in both years, and number of grain per plant in 2008. Contrary, interaction between studied factors was significant effect on plant height, grain yield per plant and 1000-grain weight in both years and number of grain per plant in 2007.

Conclusions

Cultivar Bečejka, with shorter vegetation period, produced lower plant height, first pod height, number of nodes per plant, number of pods per plant, number of grain per plant, grain yield per plant, 1000-grain weight and grain yield then cv. Balkan. From this study it may be concluded that different fertilizer treatments effected the increasing of studied quantitative traits in both soybean cultivars. Method of foliar feeding has been proved as an effective tool for increasing of grain yield in both cultivars. However, Urea + Ferticare I treatment is more effective than Urea + Wuxal super in soybean. This follows from the fact that Ferticare I has higher concentration of macronutrients than Wuxal super. Generally, cultivar Balkan and treatment Urea + Ferticare I may be recommended in soybean production in localities with similar agro-ecological conditions.

Acknowledgements

The research was supported by the Ministry of Education and *S*cience, Republic of Serbia, project TR 31053.

Efekat folijarne ishrane na prinos zrna soje

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Rezime

Cilj istraživanja je bio da se oceni efekat folijarne ishrane na kvantitativne osobine (visina biljke, visine prve mahune, broj nodusa po biljci, broj mahuna po biljci, broj zrna po biljci, prinos zrna po biljci, masa 1000 zrna i prinos zrna) dve sorte soje (Balkan i Bečejka). Ispitivane sorte pripadaju različitim grupama zrenja (Balkan - I, Bečejka - 0). Upoređivane su četiri tretmana ishrane biljaka: kontrola, Urea (46 kg N ha^{-1}), Urea (46 kg N ha^{-1}) + Wuxal super (5 l ha^{-1}) i Urea (100 kg ha^{-1}) + Ferticare I (5 kg ha^{-1}). Wuxal super i Ferticare I primenjeni su folijarno u R2-R3 fazi rastenja i razvića soje. Ogledi su izvedeni u suvom ratarenju u Vojvodini na lokaciji Putinci (45° 00′ SGŠ, 19° 58′ IGD) tokom 2007. i 2008. godine. U obe godine istraživanja sorta Balkan je imala veće vrednosti za sve ispitivane osobine nego Bečejka. Rezultati su pokazali da je folijarna ishrana značajno povećala vrednosti svih ispitivanih kvantitativnih osobina. Viši prinosi postignuti su primenom Ferticare I nego primenom Wuxal super jer sadrži veću koncentraciju

makroelemenata. Folijarno prihranjivanje soje umanjilo je negativan uticaj malih količina padavina tokom letnjih meseci na prinos zrna.

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Received 24 February 2015; accepted for publication 23 March 2015