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Response of soybean to controlled release fertilizers

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Abstract
The field experiment was conducted during *kharif* season, 2023-24 with split plot design. The present investigation consists of eighteen treatment combinations replicated three times. Treatments comprised of as main plot treatments (Varieties)- *i.e.*V_1- MAUS 158, V_2- MAUS 725, V_3- KDS 726 and six fertilizer levels as sub plot treatments - *i.e.* F_1 - Control (No fertilizer), F_2 - Recommended dose of fertilizer (30: 60: 30 kg N: P_2O_5: K_2O ha^{-1}), F_3 - Controlled release fertilizer @ 6.5: 16.5: 9.6 kg N: P_2O_5: K_2O ha^{-1}, F_4 - Controlled release fertilizer @ 9.75: 24.75: 14.4 kg N: P_2O_5: K_2O ha^{-1}, F_5 - Controlled release fertilizer @ 13: 33: 19.2 kg N: P_2O_5: K_2O ha^{-1} and F_6 - Controlled release fertilizer @ 16.25: 41.25: 24 kg N: P_2O_5: K_2O ha^{-1}. The treatments were allotted randomly in each replication. The controlled release fertilizers were applied near root zone of crop at 45 DAS. The obtained results revealed that application of controlled release fertilizer @ 16.25:41.25:24 kg N: P_2O_5: K_2O ha^{-1} along with variety KDS-726 noted significantly superior growth attributes *viz.*, plant height (43.67 cm), number of nodules per plant (79.62) and number of pods per plant (80.22). Also, the total uptake (seed + straw) of N (208.97 kg ha^{-1}), P (15.62 kg ha^{-1}) and K (62.70 kg ha^{-1}) in soybean noted maximum in variety KDS-726 with fertilizer level F_6 *i.e.* controlled release fertilizer @ 16.25:41.25:24 kg N: P_2O_5: K_2O ha^{-1}.

Keywords: Controlled release fertilizers, varieties, soybean, growth attributes, uptake

Introduction
Soybean (*Glycine max* L. *Merill.*) is most important seed legume crop, belonging to family Leguminoseae. The relevance of soybean is growing due to a number of quality considerations. It is referred to "The protein hope of the future" as well as "Miracle golden bean" (Sarkar *et al*., 2002) [9] due to its high nutritional content, which includes 40-45 per cent protein and 20-25 per cent edible oil. Leucine, methionine, threonine are the high-quality amino acids found in soybean protein. It also has excellent quality of lipids with a high linoleic acid content. The application of conventional fertilizers does not match nutrint requirement of crop o match crop nutrient requirements, the ideal fertilizer should have the characteristics *viz*; the nutrient release matches the nutrient requirements of the crop throughout all of the plant growth stages. Also, it shows problem of nutrient losses through leaching, volatalization. With existing challenges on low Nutrient Use Efficiency (NUE), Controlled Release Fertilizers (CRFs) have become a potential solution by formulating them to synchronize nutrient release according to the requirement of plants.

They are produced by encapsulating the conventional soluble fertilizer material to control water entry and rate of dissolution, therefore synchronizing nutrient release. Controlled release fertilizers have the three key characteristics *viz*; single application throughout the growth season; a high rate of return to the production input and minimal negative impact on soil, water, and surrounding ecosystem. These fertilizers can cover crop nutrient needs for the full season with a single application, offering economic benefits.

Compared to the conventional fertilizers, their gradual pattern of nutrient release satisfies plant needs and therefore improves fertilizer use efficiency. The application of controlled release fertilizers decreases nutrient losses, enhance nutrient-use efficiency and potentially decrease fertilizer use by 20 to 30 percent of the recommended rate of a conventional fertilizer while, obtaining the same yield (Trenkel, 2010) [12].

Materials and Methods

This investigation was conducted at Research Farm of Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The soils of the present experimentation were classified as Vertisol soil order belonging to Parbhani soil series which comprise of fine Montmorillonite isohyperthermic family of Typic Haplusterts. The required quantity of controlled release fertilizer was prepared at laboratory of Department of Agronomy by mixing the macro and micro nutrients containing fertilizers.

The experiment was laid out in split plot design. It consists of eighteen treatment combinations replicated three times. Treatments comprised of as main plot treatments (Varieties)- *i.e.*V_1- MAUS 158, V_2- MAUS 725, V_3- KDS 726 and six fertilizer levels as sub plot treatments - *i.e.* F_1 - Control (No fertilizer), F_2 - Recommended dose of fertilizer (30:60:30 kg N:P_2O_5:K_2O ha^{-1}), F_3 - Controlled release fertilizer @ 6.5:16.5:9.6 kg N:P_2O_5:K_2O ha^{-1}, F_4 - Controlled release fertilizer @ 9.75:24.75:14.4 kg N:P_2O_5:K_2O ha^{-1}, F_5 - Controlled release fertilizer @ 13: 33: 19.2 kg N:P_2O_5:K_2O ha^{-1} and F_6 - Controlled release fertilizer @ 16.25:41.25:24 kg N:P_2O_5:K_2O ha^{-1}. The fertilizers urea, SSP and MOP were applied for sources of N, P and K, respectively for soybean. The data on growth attributes was recorded at different growth stages of soybean *i.e.* 30, 45, 60, 75, 90 DAS and at harvest. The total uptake *i.e.* seed + straw of N, P and K was calculated at harvest stage.

Nutrient uptake of straw/seed for major nutrients (NPK)

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Dry matter yield (kg ha}^{-1}) \times \text{Nutrient content (\%)}}{100}$$

Results and Discussion

Effect of varieties and controlled release fertilizer levels on growth attributes of soybean

Plant height (cm)

The results regarding the plant height of soybean were recorded at 15 days interval *i.e.* 30, 45, 60, 75, 90 DAS and at harvest stage are presented in Table 1.

The plant height was significantly influenced by the different varieties of soybean crop. The taller plants were recorded with the variety KDS-726 (V_3) with values 22.03, 30.66, 41.78, 42.97, 43.30 and 43.67 cm at 30, 45, 60, 75, 90 DAS and at harvest, respectively. It was statistically at par with the variety V_1 (MAUS- 158). The dwarf plant at all the growth stages were recorded in the variety V_2 (MAUS-725) with values 17.92, 21.4, 28.23, 31.99, 32.32 and 32.69 cm at 30, 45, 60, 75, 90 DAS and at harvest, respectively.

Among different controlled release fertilizer levels, Table 1 showed that the taller plants were recorded with treatment F_6 receiving controlled release fertilizer @ 16.25:41.25:24 kg N: P_2O_5: K_2O ha^{-1} with height 21.69, 19.39, 29.80, 40.37, 41.72, 42.22, 43.56 cm at 30, 45, 60, 75, 90 DAS and at harvest, respectively which was statistically at par with treatment of controlled release fertilizer @ 13: 33: 19.2 kg N: P_2O_5: K_2O ha^{-1} (F_5). The treatment F_1 without any fertilizer treatment has recorded lowest plant height at all the growth stages of soybean crop.

The plant height increased with application of controlled release fertilizer and varietal effect might be due to positive effect of controlled release fertilizer on plant metabolic activity which increased photosynthesis in the soybean. Similar results are reported by Noor *et al.*, (2017) [7] found that the application of polymer coated DAP has enhanced plant height because of the superiority of polymer coated phosphatic fertilizers was probably due to maintaining the intimate availability of P in the soil for developing root adjacent to fertilizer granules. The results are in confirmity with Ali *et al.*, (2017) [3] and EI-Tohamy *et al.*, 2009 [4].

Number of nodules per plant

The data presented in Table 2 indicated that maximum and minimum number of nodules per plant were recorded with variety KDS-726 (72.47) and MAUS 725 (57.28), respectively. Variety MAUS-158 recorded 59.57 nodules per plant. Jamal *et al.*, (2010) [13] has observed the same results in two different groundnut varieties fertilized with slow release sulphur fertilizers.

The results showed that treatment of controlled release fertilizer @ 16.25:41.25:24 kg N: P_2O_5: K_2O ha^{-1} **(**F_6) has recorded maximum number of root nodules per plant (79.65 $plant^{-1}$). The absolute control plot has observed with lowest number of root nodules per plant (53.37) per plant followed by F_3 treatment of controlled release fertilizer @ 6.5:16.5:9.6 kg N: P_2O_5: K_2O ha^{-1} recording 54.68 root nodules per plant. The fertilizer levels F_2, F_3, F_4, F_5 recorded 59.01, 54.68, 63.91, 68.00 nodules per plant, respectively. The controlled release of nitrogen through these fertilizers enhanced the nodulation as excess amount of available nitrogen was present as per the need of crop. Kaushal *et al.*, 2006 [16], Takahashi *et al.*, 2010 [10] and Ohyama *et al.*, 2019 [8] reported the same line of results in soybean.

Number of pods per plant

The data regarding the number of pods per plant were recorded at 60, 75 DAS and at harvest of crop. The data presented in Table 3 showed that the number of pods per plant in soybean fertilized with different rate of controlled release fertilizers significantly differed in each treatment and variety. It was ranged from 28.78 to 80.22 pods $plant^{-1}$ at different growth sstages of soybean.

The number of pods per plant were significantly influenced by the different variety of crop. The highest number of pods per plant were observed in variety KDS-726 (V_3) which were 36.43, 63.63 and 66.47 pods per plant at 60 and 75 DAS and at harvest, respectively followed by variety (MAUS-158) which was found 55.08, 60.01 and 62.18 at 60 and 75 DAS and at harvest, respectively. Variety (MAUS-725) has found with lowest number of pods at all the growth stages of crop.

Among the six fertilizer levels the treatment of controlled release fertilizer @ 16.25:41.25:24 kg NPK ha^{-1} (F_6) has recorded maximum number of pods $plant^{-1}$ which were 66.33, 79.56 and 80.22 pods at 60, 75 DAS and at harvest (80.22) which was statistically at par with treatment F_5 receiving controlled release fertilizers @ 13:33:19.2 kg NPK ha^{-1} with values 65.3, 76.09, 76.76 at 60 DAS, 75 DAS and at harvest respectively. The treatment of recommended dose of fertilizer has recorded 35.84, 47.44 and 49.31 pods per plant at 60 and 75 DAS and at harvest, respectively followed by treatment of controlled release fertilizers @ 6.5:16.5:9.6 kg NPK ha^{-1} (F_3).

The lowest number of pods were associated with the absolute control treatment without any fertilizer dose. Increased number of pods per plant might be due to significant increase in growth, plant height and efficient nutrient utilization. EI-Tohamy *et al.*, (2009) [4] reported that

slow release nitrogen fertilizers applied to bean resulted in higher number of pods as compared to conventional fertilizers. Also, there was increase in number of pods per plant in rapeseed with controlled release fertilizers as compared to soluble fertilizers due to increased nutrient use efficiency of crop (Tian *et al.*, 2016) [11].

Effect of varieties and controlled release fertilizer levels on total N, P and K uptake

Total N uptake

In case of different varieties of soybean, the higher total nitrogen uptake (175.44 kg ha^{-1}) was found in variety V_3 - KDS 726 followed by variety, V_1 - MAUS 158 (165.79 kg ha^{-1}). Abou-Zied *et al.*, (2014) [1] has reported the same findings that slow-release nitrogen fertilizers have increased total nitrogen uptake in soybean.

Among different controlled release fertilizer levels, the highest values of total nitrogen uptake at harvest of soybean was noted in fertilizer treatment F_6 provided with controlled release fertilizer @ 16.25:41.25:24 kg $N:P_2O_5:K_2O$ ha^{-1} (208.97 kg ha^{-1}) which was remains at par with the treatment of controlled release fertilizer @ 13: 33: 19.2 kg $N:P_2O_5:K_2O$ ha^{-1} (F_5). The plot with absolute control recorded minimum total nitrogen uptake (97.01 kg ha^{-1}) followed by the F_3 treatment which was having dose of controlled release fertilizer @ 6.5:16.5:9.6 kg N: P_2O_5: K_2O ha^{-1}. The low total nitrogen uptake in conventional fertilizer treatment might be associated with large volatilization and leaching in alkaline soils. The superiority of slow release and controlled release fertilizers can be affirmed by giving significantly higher total nitrogen uptake. The similar results were reported by EI- Tohamy *et al.*, 2009 [4]. High nutrient use efficiency of nitrogen has resulted increased total N uptake (Ahmed and Fahmy, 2017) [2].

Total P uptake

In case of different varieties of soybean, the variety KDS-726 was superior in case of total phosphorus uptake at harvest (13.81 kg ha^{-1}) which was found to be at par with variety V_1 - MAUS 158 with uptake value 12.34 kg ha^{-1}. MAUS 725 (V_2) has recorded minimum uptake at harvest. The controlled release by coated fertilizers has resulted in more uptake of phosphorus (Tian *et al.*, 2016) [11].

Among controlled release fertilizer levels, application of fertilizer level F_6 - controlled release fertilizer @ 16.25:41.25:24 kg $N:P_2O_5$: K_2O ha^{-1} was found superior among all the six treatments (14.58 kg ha^{-1} uptake harvest) followed by the treatment F_5 - controlled release fertilizer @ 13: 33: 19.2 kg N: P_2O_5: K_2O ha^{-1} with value 13.14 kg ha^{-1}. While, the minimum total P uptake was recorded in absolute control treatment followed by treatment F_3 - controlled release fertilizer @ 6.5:16.5:9.6 kg N: P_2O_5: K_2O ha^{-1}.

The uptake of phosphorus by soybean might be enhanced due to reduction in phosphate fixation reaction with soil constituents through slow release of phosphate anions with polymer coating. The results are in accordance with findings of EI- Tohamy *et al.*, 2009 [4] who found that the total P uptake has increased in response to slow release or controlled release fertilizers. The attapulgite coated slow-release fertilizers have shown increased P uptake in maize due to the availability of nutrients at specific range with particular stage of a crop and due to gradual release of P from fertilizer (Guan *et al.*, 2013) [5].

Total K uptake

The results from Table 3 indicates that KDS-726 variety is dominant in total K uptake at harvest of crop. It was found with uptake 49.92 kg ha^{-1}. Minimum value of uptake was recorded in variety V_2 i.e. MAUS-725 which was 43.23 kg ha^{-1} at harvest of soybean crop. As described by El-Tohamy *et al.*, (2009) [4] the uptake of potassium by bean plants has enhanced with treatments of controlled release nitrogen fertilizers.

Data reveals that the treatment of controlled release fertilizer @ 16.25:41.25:24 kg $N:P_2O_5:K_2O$ ha^{-1} (F_6) has noted maximum total K uptake (62.70 kg ha^{-1}) at harvest stage followed by the treatment F_5 - controlled release fertilizer @ 13: 33: 19.2 kg $N:P_2O_5:K_2O$ ha^{-1} (59.54kg ha^{-1}). Minimum K uptake was recorded in absolute control plot which was 26.92 kg ha^{-1}. The findings are in accordance with Abou-Zied *et al.*, (2014) [1] reporting that application of sulphur coated urea and bentonite coated urea has increased total potassium uptake in soybean due to slow and gradual release of nutrients from fertilizer as per the needs of crop. This result was in conformity with Tian *et al.*, 2016 [11].

Table 1: Effect of varieties and controlled release fertilizer levels on plant height of soybean

Treatments	Plant height (cm)					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At Harvest
Varieties (V)						
V_1 - MAUS 158	16.80	25.45	33.97	34.64	34.98	35.34
V_2 - MAUS 725	15.62	20.10	28.23	31.99	32.32	32.58
V_3 - KDS 726	19.73	29.36	41.78	42.97	43.3	43.56
SE (m) ±	1.15	0.73	0.99	0.87	0.91	0.92
C.D. at 5%	NS	2.02	2.74	2.41	2.53	2.55
Fertilizer levels (F)						
F_1 - Control (No fertilizer)	14.90	19.95	29.08	30.02	30.32	30.42
F_2 - Recommended dose of fertilizer (30:60:30 kg N: P_2O_5: K_2O ha^{-1})	17.06	23.30	33.15	35.96	36.06	35.51
F_3 - CRF @ 6.5:16.5:9.6 kg N: P_2O_5: K_2O ha^{-1}	16.72	23.08	33.06	35.41	35.51	35.31
F_4 - CRF @ 9.75:24.75:14.4 kg N: P_2O_5: K_2O ha^{-1}	18.15	25.75	35.1	37.27	37.77	37.80
F_5 - CRF @ 13: 33: 19.2 kg N: P_2O_5: K_2O ha^{-1}	18.088	27.95	37.19	38.82	39.32	40.16
F_6 - CRF @ 16.25:41.25:24 kg N: P_2O_5: K_2O ha^{-1}	19.39	29.80	40.37	41.72	42.22	43.56
SE (m) ±	1.52	1.16	1.74	1.49	1.52	1.62
C.D. at 5%	NS	2.36	3.56	3.05	3.1	3.31
Interaction effect (V × F)						
SE (m) ±	2.64	2.00	3.02	2.59	2.63	2.8
C.D. at 5%	NS	NS	NS	NS	NS	NS

Table 2: Effect of varieties and controlled release fertilizer levels on number of pods per plant and number of nodules per plant

Treatments	Number of pods per plant			No. of nodules per plant
	60 DAS	75 DAS	At harvest	
Varieties (V)				
V_1 - MAUS 158	36.43	60.01	62.18	59.57
V_2 - MAUS 725	51.11	57.43	57.1	57.28
V_3 - KDS 726	55.8	63.63	66.47	72.47
SE (m) ±	1.47	1.35	1.54	0.38
C.D. at 5%	4.07	3.74	4.27	1.05
Fertilizer Levels (F)				
F_1 - Control (No fertilizer)	28.78	39.73	43.40	53.37
F_2 - Recommended dose of fertilizer (30:60:30)	35.84	47.44	49.44	59.01
F_3 - CRF @ 6.5:16.5:9.6 kg NPK ha^{-1}	33.62	47.64	49.31	54.68
F_4 - CRF @ 9.75:24.75:14.4 kg NPK ha^{-1}	56.8	71.69	72.36	63.91
F_5 - CRF @ 13:33:19.2 kg NPK ha^{-1}	65.31	76.09	76.76	68.00
F_6 - CRF @ 16.25:41.25:24 kg NPK ha^{-1}	66.33	79.56	80.22	79.65
SE (m) ±	2.79	1.70	1.89	0.49
C.D. at 5%	8.20	4.46	5.55	1.44
Interaction effect (V × F)				
SE (m) ±	4.84	2.94	3.28	0.85
C.D. at 5%	9.88	6.00	9.64	2.49

Table 3: Effect of varieties and controlled release fertilizer levels on total N, P and K (kg ha^{-1}) uptake in soybean

Treatments	Total N uptake			Total P uptake			Total K uptake		
	Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
Varieties (V)									
V_1 - MAUS 158	150.74	15.05	165.79	7.21	5.13	12.34	34.88	11.72	46.6
V_2 - MAUS 725	131.64	11.94	143.58	5.86	4.89	10.75	31.92	11.31	43.23
V_3 - KDS 726	158.69	16.55	175.24	8.25	5.56	13.81	37.69	12.23	49.92
SE (m) ±	2.67	0.94	3.32	0.45	0.28	0.54	0.96	0.72	1.20
C.D. at 5%	7.40	3.68	13.01	1.25	1.09	2.11	2.66	2.14	3.72
Fertilizer levels (F)									
F_1 - Control (No fertilizer)	88.33	8.68	97.01	4.04	2.96	7.00	19.73	7.19	26.92
F_2 - Recommended dose of fertilizer (30:60:30)	131.02	14.26	145.28	6.55	4.97	11.52	31.09	11.01	42.1
F_3 - CRF @ 6.5:16.5:9.6 kg NPK ha^{-1}	128.60	14.38	142.98	6.53	5.42	11.95	28.39	10.73	39.12
F_4 - CRF @ 9.75:24.75:14.4 kg NPK ha^{-1}	160.24	15.13	175.37	7.77	5.37	13.14	36.98	12.14	49.12
F_5 - CRF @ 13:33:19.2 kg NPK ha^{-1}	182.82	16.79	199.61	8.51	6.07	14.58	45.40	14.14	59.54
F_6 - CRF @ 16.25:41.25:24 kg NPK ha^{-1}	191.12	17.85	208.97	9.24	6.38	15.62	47.39	15.31	62.70
SE (m) ±	5.89	3.8	6.71	0.39	0.29	0.45	1.42	1.25	1.86
C.D. at 5%	14.04	11.17	19.72	1.14	0.85	1.32	3.90	3.54	5.46
Interaction effect (V × F)									
SE (m) ±	10.21	6.58	11.11	0.67	0.50	0.78	2.46	2.16	3.23
C.D. at 5%	30.01	19.43	32.24	1.96	1.47	2.29	6.02	6.41	9.59

Conclusion

Application of controlled release fertilizer @ 16.25:41.25:24 kg N: P_2O_5: K_2O ha^{-1} was more effective treatment than the others with variety KDS-726 in different growth attributes. The treatment is also superior in case of total (Seed + straw) uptake of N, P and K in soybean. Also, the variety KDS-726 was found to be superior to other varieties. The application of controlled release fertilizers near root zone of crop has found effective as compared to the broadcasting of conventional fertilizers.

References

1. Abou-Zied ST, Abd El-Lateef HE, Sibak A, Hozayn MM, Soad M, El-Ashry AL, *et al*. Effect of different slow release nitrogen fertilizer forms on yield and chemical constituents of maize and soybean. Middle East J Agric Res. 2014;3(3):645-52.
2. Ahmed SS, Fahmy AH. Environmental impact for applications of neem cake coated urea and nano iron foliar on rationalization of chemical nitrogen fertilizers and wheat yield. J Soil Sci Agric Eng. 2017;8(11):613-20.
3. Ali I, Mustafa A, Yaseen M, Imran M. Polymer coated DAP helps in enhancing growth, yield and phosphorus use efficiency of wheat (*Triticum aestivum* L.). J Plant Nutr. 2017;40(18):2587-94.
4. El-Tohamy WA, Ghoname AA, Riad GS, Abou-Hussein SD. The Influence of slow release fertilizer on bean plants (*Phaseolus vulgaris* L.) grown in sandy soils. Aust J Basic Appl Sci. 2009;3(2):966-9.
5. Guan Y, Chao S, Yantai G, Feng-Min Li. Increased maize yield using slow-release attapulgite coated fertilizers. Agron Sustain Dev. 2013;34(3):657-65.
6. Kaushal T, Onda M, Ito S, Yamazaki A, Fujikake H, Ohtake N, *et al*. Effect of deep placement of slow-release fertilizer (Lime nitrogen) applied at different rates on growth, N fixation and yield of soybean (*Glycine max* [L.] Merr.). J Agron Crop Sci. 2006;192:417-26.
7. Noor S, Yaseen M, Naveed M, Ahmad R. Use of controlled release phosphatic fertilizer to improve

growth, yield and phosphorus use efficiency of wheat crop. J Agric Biol Sci. 2017;54(4):541-7.
8. Ohyama T, Tewari K, Ishikawa S, Tanaka K, Kamiyama S, Ono Y, *et al*. Role of nitrogen on growth and seed yield of soybean and a new fertilization technique to promote nitrogen fixation and seed yield. In: InTech; c2019. Available from: http://dx.doi.org/10.5772/66743. Accessed September 20, 2024.
9. Sarkar PK, Haque MS, Karim MA. Effects of GA3 and IAA and their frequency on application on morphology, yield contributing character and yield of soybean. Pak J Agron. 2002;1(4):119-22.
10. Takahashi Y, Makoto H, Yoshifumi N, Ohyama T. Effect of basal side dressing of various types of coated fertilizer on shoot growth, yield components and seed composition of soybean (*Glycine max* (L.) Merril.). Soil Sci Plant Nutr. 2010;52:264-73.
11. Tian C, Zhou XL, Peng J, Wang W, Zhang Z, Yang Y, *et al*. Effects of a controlled-release fertilizer on yield, nutrient uptake, and fertilizer use efficiency in early ripening rapeseed (*Brassica napus* L.). J Zhejiang Univ Sci. 2016;17(10):775-86.
12. Trenkel ME. Slow and controlled release and stabilized fertilizers: an option for enhancing nutrient use efficiency in agriculture. Paris, France: International Fertilizer Industry Association (IFA). 2010;12(3):567-79.
13. Jamal A, Moon YS, Zainul Abdin M. Sulphur-a general overview and interaction with nitrogen. Australian Journal of Crop Science. 2010 Jan 1;4(7):523-9.