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Effect of irrigation amounts and fertilization on yield and quality of soybean

Mahrous, N. M.;G. O. Mahmoud,; S. A. Safina and E. A. M. El-Haggan.
Agronomy Dep., Fac. Agric., Cairo Univ.

ABSTRACT

Two field experiments had conducted in of 2012 and 2013 summer seasons at Deir Mawas, Menia Governorate, Egypt to study the effect of irrigation amounts applied with center- pivot sprinklers and fertilization on yield and quality of soybean. The results indicated that application of 2880 m^3 /feddan (4200 m^2) significantly surpassed application of 2240 and 1600 m^3 /feddan in plant height, number of pods and seeds/plant, seed index and seed yield/plant. The highest seed yield/fed. was obtained with irrigation by 2880 m^3 /fed., which was 52.2 % higher than irrigation with 1600 m^3 /fed. (0.620 ton/fed.). The maximum oil content (20.74 %) and protein content (41.79) had achieved with irrigating by 2240 m^3/feddan. However, the highest yields of oil (266.52 kg/fed) and protein (534.88 kg/feddan) had obtained from irrigation by 2880 m^3 water/feddan.

The highest soybean plant height, number of pods and seeds/plant, seed index and seed yield/plant were obtained with addition of NPK compound (19:19:19) with15 units of each elements (F2). In addition, F2 fertilizer treatment recorded the highest values of seed, oil and protein yields/feddan and IWUE. On the other hand, application of NPK compound (19:19:19) with 7.5 Kg of each element/feddan(F4) produced the highest oil and protein contents in seeds (21.28 and 43.06 %, respectively). The interactions between the amounts of irrigation and fertilizer treatments revealed highly significant differences in plant height, number of seeds/plant, seed index, seed yields per plant and feddan, oil and protein contents and yields. Irrigation by 2880 m3 /feddan with addition NPK compound (19:19:19) with 15 Kg of each element/ feddan significantly gave the greatest values of plant height, seeds/plant, seed index, seed yield/plant and yields/feddan of seed, oil and protein.

Keywords: Soybean, Irrigation, amounts of water, center-pivot, sprinkler, NPK fertilizer, yield and quality, oil content, protein content.

INTRODUCTION

Soybean is grown for human consummation, industry and animal feed. Soybean seeds contain about 18 to 22% cholesterol free oil with 85% unsaturated fatty acids and 38 to 42% protein (Ali *et al*., 2009). In Egypt, soybean growth period range usually between 100 and 120 days and requires 325 -436 mm of water depending on the location (Ainer *et al.,* 1999).

Water shortage is one of the main constraints for economic development. Egypt has a definite amount of water that can be use for irrigation. Due to rapid population growth, increasing food requirement and limited water resources, deficit irrigation is inevitable (Kulkarni, 2011).

Decreasing plant water consumption can be achieve by using more efficient irrigation methods, plant breeding technology, longer irrigation intervals, higher moisture depletion and skipping irrigation. Center pivot systems greatly reduce excess water use by applying precise amounts of water to crops at the right times and in the right quantities. Today, center pivots in many cases are replacing surface irrigation on flat lands. These farms are being converted to mechanized irrigation for many reasons. Therefore, any procedure that can maximize the use of water in agriculture is of extreme importance to the security and economic welfare of Egypt.

Plants are more sensitive to water deficit at some stages than at other stages (Kirda, 2002). Stressful conditions, such as moisture deficiency reduces soybean yield. As the soybean plant ages from beginning bloom through seed enlargement, its ability to compensate under stressful conditions decreases and yield losses could increases (Foroud *et al*., 1993). The most important times for soybean plants to have adequate water are during pod development and seed fill (Ainer *et al.,* 1999).

Abd El-Mohsen *et al.* (2013) indicated both soybean oil and protein output per unit area significantly reduced, as water regimes increased. Skipping irrigation during vegetative, flowering and pod filling stages had no effect on economic yield and save 14% from total irrigation costs of soybean production, but skipping two or three irrigations during vegetative, flowering and pod filling stages had an effect on economic yield of soybean production.

Fertilization with N, P and K can affect yield and many physiological processes that, in turn, could influence grain yield and protein or oil concentration. Soybean has classified as a poorer responder to N, P and K fertilization compared with other grain crops although responds have observed in low testing soils (Komprath, 1974). Large soybean responses to P or K fertilization have reported in Iowa by Bharati *et al*., 1986; Mallarino *et al*., 1991; Webb *et al*., 1992 and Borges and Mallarino, 2003.

Bharati *et al.* (1986) reported that P and K applications increased soil and leaf P and K contents over time and application levels. Soybean responds to k application when the soil test levels were medium to high. Abdul Kabir (2007) found that, applied fertilizer significantly and linearly reduced all nodules and added that, applied P_2O_5 + K_2o slightly improve it.

Yao *et al*. (2009) reported that grain yields of soybean was affected by N levels, yields of low - N level and mid - N level treatments did not reach the significantly different levels, but they were obviously higher than that of high – N treatment.

The objectives of this research was to define the suitable amount of irrigation water and four fertilization treatments on seed yield and quality of soybean under condition of Menia Governorate, Egypt.

MATERIALS AND METHODS

The present study had conducted during the 2012 and 2013 summer seasons at the Deir Mawas, Menia Governorate, Egypt to study the effect of some irrigation amounts and some fertilizer treatments on yield and quality of soybean Giza 111 cultivar sown in mid May.

The soil was a sandy loam with 0.91% organic matter content, an electrical conductivity (EC) of 0.29 ds m^{-1} and a pH of 7.80. Total nitrogen content was 0.46%, available phosphorus was 4.81 mg kg^{-1}, available potassium was 84.00 mg kg^{-1} and no salinity problem had observed.

The experiments had laid out in a strip-plot design with three replications. The vertical plots were belonged for amount of irrigation water (2880, 2240 and 1600 m^3 water/fed. and the horizontal plots had devoted for the following four fertilizer treatments:

1. Addition of 25 Kg N + 31 kg P_2O_5 +24 kg K_2o / fed. (F_1).
2. Addition of NPK compound (19:19:19) with 15 units of each elements /fed. (F_2).
3. Addition of 12.5 Kg N + 15.5 kg P_2O_5 + 12.0 kg K_2O (F_3)
4. Addition NPK compound (19:19:19) with 7.5 Kg of each elements /fed. (F_4).

The experimental plots consisted of 7.0 m long and 5.0 m width (35 $m^{2)}$. Ditches of 1.5 m in width to avoid lateral movement of irrigation water had done. The irrigation system was pivot irrigation. The amount of irrigation water were (2880, 2240 and 1600 m^3 water/fed.

The experiments had sown on mid May in 2012 and 2013 seasons. Soybean seeds were planted in rows and spaced between hills 12.5 cm. Seeds were treated with *Rhizobium japonicum* immediately before seeding.

At maturity to avoid marginal effects, soybean plants of 15 m^2 had harvested. Ten guarded plants had randomly sampled from each plot to measure plant height, number of branches $plant^{-1}$, number of pods $plant^{-1}$, number of seeds $plant^{-1}$ and seed yield $plant^{-1}$. Seed index and yield per fed were determined on plot basis. Seed oil content was determined using Soxhlet apparatus and diethyl ether as a solvent. Protein percentage of seeds had measured according to AOAC (2000). Protein yield ha^{-1} and oil yield ha^{-1} had calculated by multiplying seed yield $ha^{-1}$by protein and oil percentage, respectively. Irrigation water-use efficiency (IWUE) values had calculated according to (Bhattarai *et al*., 2006) as follow: $IWUE = (E_y / I_r) \times 100$

Where IWUE is irrigation water use efficiency (kg/m^3), E_y is the economical yield (kg/feddan) and I_r is the amount of applied irrigation water (m^3).

Collected data had subjected to the proper of statistical analysis of variance (ANOVA) of split plot design as mentioned by Gomez and Gomez (1984). Data of the two seasons had tested for homogeneity using Bartlett's (1937) test and it was found to be homogeneous so the data were combined for analysis. The combined ANOVA had carried out according to Steel *et al*. (1997). Least Significant Difference (LSD) had applied to detect statistical differences among irrigation and fertilizers treatment means, when the F-test for these treatments was significant at 5% probability level.

RESULTS AND DISSECTIONS

Effect of irrigation water amount, fertilizer treatments and interaction of both on soybean traits will be present and discuss only combined seasons as follows:

Effect of irrigation amount

Results presented in Table 1 show that plant height, number of pods and seeds/plant, seed index and seed yield/plant had significantly affected by amount of irrigation water.

Applications of 2880 m^3 water/feddan significantly surpassed 2240 and 1600 m^3 water/fed. in plant height (121.6 cm), number of pods/plant (85.5), seeds/plant (86.6), seed index (22.7 g) and seed yield/plant (19.7 g). Meanwhile, 1600 m^3 water/fed. produced the lowest values of the previous traits. This could attribute to the fact that as leaf water potentials decreased, leaf enlargement inhibited earlier and more severely than photosynthesis or respiration. These results are in agreement with those obtained by Kranz *et al*., 1998 and Abd El-Mohsen *et al.*, 2013.

Results in Table (2) indicated that seed yield /fed., oil content, oil yield/fed., protein content, protein yield/fed. and IWUE (kg m^{-3}) were significantly affected by irrigation water amounts. Seed yield is the combined function of different components and it is a complex character depending upon a large number of environmental, morphological and physiological characters. The highest seed yield/fed. (1.298 ton) had obtained with irrigation by 2880 m^3 /fed. per season, which was 52.2 % higher than that of 1600 m^3 water/fed. Reduction in soybean crop yield as a result of water stress has also been reported by Desclaux *et al*., 2000; Behtari and Abadiyan, 2009; Kobraee *et al*., 2011, Masoumi *et al.,* 2011 and Abd El-Mohsen *et al.*, 2013.

Data in Table 2 reveal that amount of irrigation had a significant effect on oil and protein content and yield/fed. The results in Table 2 showed that significant suppressive effect on oil content percentage by different amounts of irrigation. The maximum oil content (20.74 %) was found with application of 2240 m^3 water/fed. Application of 1600 m3 water/fed significantly gave the lowest oil content (20.28 %). In general, oil content of soybean seeds declined gradually as the amount of water reduced from 2880 to 1600 m^3 /fed. This result is in general agreement with those obtained by Kirnak *et al*. (2010). Reduction of the grain oil percentage due to water deficit had been reported in soybean (Abd El-Mohsen *et al.*, 2013).

Oil yield per unit area is a complex character determined by genetic and environmental factors, as well as its interaction. Regarding oil yield of soybean, data in Table 2 indicate that different amount of water had highly significant effect on oil yield/fed. Irrigation by 2880m^3/fed yielded the maximum oil yield (266.52 kg/fed. Irrigation with 1600 m3 water/fed., significantly yielded the lowest oil yield (125.76 kg/fed.). The reduction in oil yield with increasing severe water regime resulted from reducing seed yield and oil percentage (Table 2).

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These results confirmed results of Naderi *et al.* (2005). Sufficient irrigation is useful to increase the seed and oil yield was decided by Roshdi *et al*., 2006 and Abd El-Mohsen *et al.*, 2013.

As shown in Table 2 amount of irrigation had significant effects on content and yield of protein. Seed protein content (41.86%) was significantly higher when crop was irrigated with 1600 m^3 /fed in comparison with 2240 and 2880 m^3 water /fed., It seems that the lower applied amount of water forced the plant metabolism to increase the protein synthesis in seeds. Increasing seed protein percentage under water stress was also reported in soybean by Ghassemi and Farshbaf, 2012 and Abd El-Mohsen *et al.*, 2013.

Amount of irrigation significantly affected protein yield/ feddan (Table 2). The highest (534.88 kg/fed.) and the lowest (259.39 kg/fed.) protein yield belonged to 2880 and 1600 m^3 water/fed, respectively. The extents of these reductions related to the variation in soybean seed yield under different irrigation amounts. This result is in general agreement with the results reported by Cober and Voldeng (2000), Behtari and Abadiyan (2009) and Abd El-Mohsen *et al.* (2013).

Irrigation water use efficiency was significantly affected by amount of irrigation (Table 2). Irrigation with 2880 m^3 water/fed. had the highest IWUE (0.452 kg/ m^3 water) in comparison with the 1600 m^3 water/fed. that had the lowest values of 0.388 kg/ m^3 water.

In general, it was observed that among the various amount of irrigation (Table 2), maximum seed yield (1.298 ton/fed.), oil yield (266.52 kg/fed.), and protein yield (534.88 kg/fed.), was noted when crop was irrigated with 2880 m^3 water/fed..

Effect of fertilizer treatments

Results in Table (3) show that significant difference between fertilizer treatments in its effect on all studied traits of soybean except, number of branches/plant. The tallest soybean plant(115.1 cm), highest number of pods (75.7), seeds(83.6) and seed yield/plant (17.8 g) and seed index (21.1g) were obtained with addition NPK compound (19:19:19) with 15 Kg of each elements/ feddan. On the other hand, the lowest values were obtained with fertilization by NPK compound (19:19:19) with 7.5 Kg of each element/ feddan.

Data presented in Table (4) indicated that the measured parameters had significantly affected by the fertilizer treatments. Application NPK compound (19:19:19) with 15 Kg of each fertilizer element/feddan recorded, the highest values of seed yield (1.032 ton), oil yield (211.77 kg), proteins yield(434.87 kg) per feddan and IWUE (0.456 kg/m^3 water). On the other hand, the highest oil and protein content in soybean seeds (21.28 and 43.06 %, respectively) were obtained with application NPK compound (19:19:19) with 7.5 Kg of each element/feddan (F4). This result is in general agreement with the results reported by Mahmoud, *et al.* (2013).

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Effect of irrigation amount × fertilizer treatments interaction

It is evident that the interactions between the amount of irrigation water and fertilizer treatments revealed highly significant differences in plant height, seeds/plant, and seed index, seed yield per plant and per feddan as well as content and yield of oil and protein (Tables 5 and 6). Moreover, the interaction of applied amount of water × fertilizer treatments did not significantly affect branches/plant, pods/plant and IWUE (Tables 5 and 6). Similar results were reported by Kirnak *et al*., 2010; Kobraee *et al*., 2011 and Aminifar *et al*., 2012.

As shown in Tables 5 and 6, soybean plants received NPK compound (19:19:19) with 15 units of each element /fed. and irrigated with 2880 m^3 water/fed. significantly gave the greatest values of plant height (130.0 cm), number of seeds/plant (96.0), seed index (23.1g), seed yield/plant (22.2 g), seed yield/fed. (1,383 ton), oil yield/fed. (290.79 kg) and protein yield/fed. (570.15 kg).

Table 5. Effect of irrigation amount × fertilizer treatments on some soybean agronomic traits (combined over 2012 and 2013 seasons).

Irrigation amounts (m3/fed.)	Fertilizer treatments	Plant height cm)	Branches /plant (no)	Pods / plant (no)	Seeds/ plant (no)	Seed index (g)	Seed yield / plant (g)
2880	F_1	123.7	3.2	89.3	95.2	22.8	21.7
	F_2	130.0	3.2	91.8	96.0	23.1	22.2
	F_3	113.2	2.8	82.8	79.3	22.5	17.8
	F_4	119.7	2.8	78.2	76.0	22.3	17.0
2240	F_1	120.0	3.0	84.0	81.2	21.1	17.1
	F_2	123.0	3.0	79.2	87.8	20.4	17.9
	F_3	103.8	2.8	74.7	82.0	20.3	16.6
	F_4	111.0	2.8	68.2	77.8	19.8	15.4
1600	F_1	83.3	2.0	53.8	63.5	20.3	12.9
	F_2	92.7	2.0	56.0	66.8	19.9	13.3
	F_3	81.8	2.0	44.8	63.7	18.9	12.0
	F_4	74.0	1.3	44.2	69.8	17.0	11.8
$LSD_{0.05}$		6.0	ns	ns	5.0	0.8	1.0

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تأثير كمية مياه الرى والتسميد على محصول فول الصويا وجودته

نبيل محمد محروس، جمالات عثمان محمود، سيد أحمد سفينه وأيمان عبد اللطيف محمد أحمد الهجان
قسم المحاصيل – كلية الزراعة - جامعة القاهرة

أجريت تجربتان حقليتان في محافظة المنيا مركز ديرمواس خلال الموسم الصيفي ٢٠١٢ ، ٢٠١٣ لدراسة تأثير كمية المياة المضافة للفدان خلال الوسم عن طريق الري بالرش المحوري (البيفوت) ومعاملات التسميد علي محصول فول الصويا وجودتة. **ويمكن تلخيص أهم النتائج المتحصل عليها فيما يلي:** أظهرت النتائج أن إضافة ٢٨٨٠ م٣/ف خلال الموسم أعطي تأثير عالي المعنوية علي صفات طول النبات ، عدد القرون ، عدد البذور علي النبات ، ودليل البذرة ومحصول النبات عن إضافة ٢٢٤٠ م٣/ف او ١٦٠٠ م٣/ف. كما أوضحت النتائج ان إضافة ٢٨٨٠ م٣/ف ماء خلال الموسم اعطي اعلي محصول من وحدة المساحة عن إضافة ١٦٠٠ م٣/ف وكانت الزيادة ٥٢.٢ %. واظهرت النتائج أن أعلي محتوي للبذور من الزيت (٤١.٧٩ %) والبروتين (٤١.٧٩ %) ناتج من إضافة ٢٢٤٠ م٣/ف خلال الموسم. بينما كان أعلي محصول زيت من الفدان (٢٦٦.٥٢ كجم/ف) ومحصول البروتين (٥٣٤.٨٨ كجم/ف) عند الري ٢٨٨٠ م٣/ف خلال الموسم. كما أوضحت النتائج أن التسميد بمركب NPK (١٩:١٩:١٩) بمعدل ١٥ وحدة من كل عنصر أظهر تفوق عالي في صفات طول النبات وعدد القرون والبذور علي النبات ودليل البذرة ومحصول النبات ومحصول الفدان من البذور والزيت والبروتين وكفاءة استخدام المياة. بالاضافة إلي أن إضافة مركب NPK (١٩:١٩:١٩) بمعدل ٧.٥ وحدة من كل عنصر/ف أعطي أعلي محتوي من الزيت والبروتين في البذور (٢١.٨ و ٤٣.٠٦ % علي التوالي). أظهر التفاعل بين كمية المياة المضافة للفدان خلال الوسم ومعاملات التسميد تأثير عالي المعنوية علي صفات طول النبات وعدد بذور النبات ودليل البذرة ومحصول بذور النبات والفدان ومحتوي بذور فول الصويا من الزيت والبروتين. أشارت النتائج الي أهمية إضافة كمية المياة ٢٨٨٠ م٣/ف خلال الموسم مع إضافة المركب NPK (١٩:١٩:١٩) بمعدل ١٥ وحدة من كل عنصر للفدان أعطي أعلي قيمة من طول النبات وعدد بذور النبات ودليل البذرة ومحصول البذور للنبات والفدان ومحصول الزيت والبروتين للفدان.

الكلمات الدالة: فول الصويا- كمية مياه الرى – التسميد- محصول البذور والزيت والبروتين

قام بتحكيم البحث

أ.د / أحمد نادر السيد	**كلية الزراعة – جامعة المنصورة**
أ.د / المتولى عبد اللة المتولى	**كلية الزراعة -جامعة القاهرة**

Table 1. Effect of irrigation water amount on some soybean agronomic traits in 2012 and 2013 seasons and its combined

Irrigation amount (m3 /fed.)	Plant height (cm)			Branches/Plant (no)			Pods / plant(no)			Seeds/plant(no)			Seed index(g)			Seed yield / plant (g)		
	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.
2880	123.5	119.8	121.6	2.8	3.2	3.0	85.5	85.6	85.5	86.9	86.3	86.6	22.8	22.6	22.7	19.8	19.6	19.7
2240	114.4	114.5	114.5	3.1	2.8	2.9	78.4	74.6	76.5	83.0	81.4	82.2	20.6	20.2	20.4	17.1	16.4	16.8
1600	83.8	82.1	83.0	2.1	1.6	1.8	49.8	49.6	49.7	64.4	67.5	66.0	19.4	18.6	19.0	12.5	12.5	12.5
$LSD_{0.05}$	8.5	2.9	4.0	0.5	0.5	ns	6.5	2.2	3.0	7.9	3.7	4.0	1.4	0.5	0.6	1.0	0.6	1.5

Ns= not significant

Table 2. Effect of irrigation amount on seed yield /fed., oil content, oil yield/fed., protein %, protein yield/fed. and IWUE in 2012 and 2013 seasons and its combined

Irrigation amount (m3 /fed.)	Seed yield /fed. (ton)			Oil Content (%)			Oil yield/fed. (kg)			Protein %			Protein yield/fed. (kg)			IWUE (kg m^{-3})		
	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.
2880	1.309	1.288	1.298	20.48	20.57	20.52	268	265	267	41.47	40.96	41.22	542.74	527.02	534.88	0.456	0.447	0.452
2240	1.002	0.978	0.990	20.70	20.78	20.74	207	203	205	41.62	41.95	41.79	417.38	410.22	413.80	0.447	0.437	0.442
1600	0.627	0.613	0.620	20.25	20.32	20.28	127	125	126	41.62	42.10	41.86	260.58	258.19	259.39	0.392	0.383	0.388
$LSD_{0.05}$	0.051	0.036	0.021	ns	ns	0.01	18	19	5	ns	ns	0.02	19.80	12.10	9.64	0.036	0.011	0.007

Ns=not significant

Table 3. Effect of some fertilizer treatments on some soybean agronomic traits in 2012 and 2013 seasons and its combined

Fertilizer treatments	Plant Height (cm)			Branches/Plant (no)			Pods / plant (no)			Seeds/plant (no)			Seed index (g)			Seed yield / plant (g)		
	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.
F_1	109.6	108.4	109.0	2.7	2.8	2.7	74.6	76.9	75.7	80.0	79.9	79.9	21.5	21.3	21.4	17.3	17.1	17.2
F_2	115.1	115.3	115.2	2.8	2.7	2.7	76.9	74.4	75.7	84.3	82.8	83.6	21.3	21.0	21.1	18.1	17.5	17.8
F_3	102.2	97.0	99.6	2.8	2.3	2.6	69.0	65.9	67.4	75.6	74.4	75.0	20.8	20.3	20.6	15.8	15.2	15.5
F_4	102.1	101.0	101.6	2.4	2.2	2.3	64.6	62.4	63.5	72.6	76.6	74.6	20.1	19.3	19.7	14.7	14.8	14.7
$LSD_{0.05}$	6.3	4.9	3.0	ns	ns	ns	4.3	4.8	2.0	9.8	4.0	3.0	0.8	0.9	0.5	0.6	0.8	0.5

Ns=not significant

Table 4. Effect of fertilizer treatments on Seed yield /fed., Oil content, Oil yield/fed., Protein %, Protein yield/fed. and IWUE in 2012 and 2013 seasons and its combined.

Fertilizer treatments	Seed yield /fed. (ton)			Oil content (%)			Oil yield/fed. (kg)			Protein (%)			Protein yield/fed. (kg)			IWUE (kg m^{-3})		
	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.	2012	2013	Comb.
F_1	1.007	0.979	0.993	20.39	20.54	20.47	206	201	203	40.37	40.84	40.60	406.94	399.81	403.38	0.445	0.431	0.438
F_2	1.036	1.028	1.032	20.53	20.35	20.44	213	210	212	42.58	42.11	42.35	440.04	429.70	434.87	0.458	0.454	0.456
F_3	0.955	0.917	0.936	19.77	20.00	19.88	188	184	186	40.40	40.53	40.47	386.82	369.17	378.00	0.421	0.401	0.411
F_4	0.919	0.915	0.917	21.21	21.34	21.28	196	195	196	42.94	43.19	43.06	393.79	395.23	394.51	0.404	0.403	0.403
$LSD_{0.05}$	0.063	0.036	0.031	ns	ns	0.02	17	18	6	0.10	0.01	0.13	20.16	11.54	11.21	0.031	0.019	0.008

F_1:Addition of 25 Kg N + 31 kg P_2O_5 +24 kg K_2o / fed.
F_2:Addition of NPK compound (19:19:19) with 15 units of each elements /fed.
F_3:Addition of 12.5 Kg N + 15.5 kg P_2O_5 + 12.0 kg K_2O
F_4:Addition NPK compound (19:19:19) with 7.5 Kg of each elements /fed.