ISSN 1313 - 8820
Volume 2, Number 2
June 2010

AGRICULTURAL SCIENCE AND TECHNOLOGY

2010

An International Journal Published by Faculty of Agriculture,
Trakia University, Stara Zagora, Bulgaria

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Trakia University
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Agricultural Science and Technology
Faculty of Agriculture, Trakia University
Student's campus, 6000 Stara Zagora
Bulgaria
Telephone.: +359 42 699330
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Technical Assistance:
Nely Tzvetanova
Telephone.: +359 42 699446
E-mail: ascitech@uni-sz.bg

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Potassium fertilization on cotton

G. Panayotova*, N. Valkova

Cotton and Durum Wheat Research Institute, 6200 Chirpan, Bulgaria

Abstract. *Research studies on cotton potassium fertilization in the last years at the Cotton and Durum Wheat Research Institute – Chirpan, Bulgaria have been reviewed. The soil Eutric vertisols was well supplied with available potassium (31-43 mg/100 g soil). The effect of K application was not clearly established. At K_{160} the seed-cotton yield increased with 6.4 % compared to the unfertilized. K_2O use efficiency was 0.18-0.61 kg of seed-cotton. For 100 kg seed-cotton yield it was necessary to apply 3.36-4.94 kg K_2O. Production of dry matter was 5.0 % higher at 160 kg K_2O/ha. The concentration in the seeds was considerably higher (1.3-1.4 %) in comparison with the lint (0.5-0.98 %). The total annual potassium uptake was 55-115 kg/ha. The changes of quality indexes were not essential. The difference between KNO_3, KCL and $NaKNO_3$ with respect to yield and quality was insignificant. The optimum balance was created at applied 70 kg K_2O/ha.*

Keywords: potassium, cotton, soil, yield, uptake, balance.

Introduction

Cotton is a main raw material source for the textile industry and its use ensures the production of healthful clothes. There is a constant increase of its utilization in the world from nearly 11 million t in 1961-1965 to up to 19.3 million t in the last years. Beside the main product - lint, the cotton plants are also used to obtain seeds rich of oils (20-22 %) and with high protein content. The cotton ranks on sixth place in the world by sowed fields, while in total and net profit per hectare it takes one of the first places. In Europe the largest amount of cotton is grown in Greece and Spain. In Bulgaria the areas, yields and production considerably change - from 760 ha in 1910 to 143 000 ha in 1951-1955. The areas were very reduced in the last years.

Potassium is the nutrient element third in significance, which performs numerous physiological and biochemical functions in the plants. Unlike N and phosphorus, it does not enter in structural organic compounds, it is in a free state but in spite of that it plays an important role to regulate the physical state of the colloids, it activates a number of enzyme systems, transforms the synthesis of carbohydrates, energy balance, nitrogen exchange, etc. It influences positively the plant resistance to unfavourable stress condition: low and high temperatures, drought, lodging, diseases, etc. In Bulgaria the application of potassium fertilizers has been insignificant in the last years, mainly in the form of foliar feeding. According to some authors potassium affects positively cotton productivity (Clement-Bailey and Gwathmey, 2007; Ebelhar et al., 2005; Paschalidis et al., 2002), it does not prove essential influence according to others (Pettigrew et al., 2005; Panayotova, 2008). Cormus and Kanat (1998) reported that K treatment in different rates produced significant seed-cotton and lint yield responses, and a higher boll weight compared with the untreated control. Lint quality values were not affected by any K treatment.

The object of this study was on the base of long-term research results of potassium fertilization to analyze the nutrient element effect on cotton productivity, soil potassium supply and the need of K for forming a product unit.

Material and methods

The experiments were conducted at the Cotton and Durum Wheat Research Institute in Chirpan, Bulgaria with Chirpan 539 cotton cultivar at cotton-durum wheat (Tr. durum Desf.) crop-rotation under non-irrigated conditions. Four potassium rates - 0 , 80 , 120 and 160 kg/ha were applied. The experimental designs were a randomized block with four replications. Potassium fertilizer was applied by hand after wheat harvest and incorporated at ploughing. Cotton seeds were sown within 20-30 April every year at a seeding rate of 14-16 seed.m-2 with 0.60 m between rows space. Weeds were controlled with preplant and preemergence herbicides. There were two harvests made by hand.

The soil type at the Institute region was classified as Eutric Vertisols (FAO), defined by the sandy-clay composition, with high humidity capacity and small water-permeability. The soil was with sorbcium capacity 35-50 mequ/100g soil, bulk weight – 1.0-1.2 g.cm-3, specific gravity – 2.6-2.7, humus content – 2.0-2.4%, mineral N - 20-25 ppm, available phosphorus - 2-6 ppm. Soil samples were taken from a depth of 0-60 cm. Analyses were made on available potassium (mg/100g soil) by the acetate-lactate method. There was established the total seed-cotton yield in kg/ha. Five plants harvested per plot were separated into leaves, stems and fruiting forms. Mature bolls were separated into lint, seed and burs. The bur fraction included squares, flowers, immature bolls and burs from mature bolls. Plant parts were dried at 60C, weighted and sieved. The potassium content in plant parts (% of dry matter) was analyzed by flame photometrically.

K content ($kg.ha^{-1}$) in plants was the product from dry matter yield ($kg.ha^{-1}$) and P concentration (%). K use efficiency (effect of 1 kg fertilizer) in kg seed cotton = Y at K_x - Y at $N_0P_0K_0$ / K_x, where: Y is

* e-mail: galia_panayotova@abv.bg

seed cotton yield, K_x – applied rate K, $N_0P_0K_0$-unfertilized. Expense of K for 100 kg seed cotton is K uptake /seed cotton yield 100.

Results and discussion

Supply of Eutric vertisols with potassium

Cotton may be successfully grown on soil type Eutric vertisols and Eutric luvisols in the Southern Bulgarian regions with favorable temperature conditions and in some Northern Bulgarian regions, such as Pleven, Svishtov, Pavlikeni, etc. on chernozems soils which have favourable physical and chemical properties. The soils, where the cotton has been planted are poor to medium supplied with nitrogen, poorly supplied with phosphorus and well provided with potassium (Table 1). The total potassium content in the soils, as compared to nitrogen and phosphorus is high (1-3 %). The available potassium for the plants is usually identified with the exchangeable form and constituted 1-3 % of the total K supply.

Table 1. Soil characteristics in cotton fields (means of the different farms), 0-30 cm depth

Soil	N		P_2O_5		K_2O	
	Total %	N_{min} mg/kg	Total %	Available mg/kg	Total %	Available mg/kg
Calcic chernozems	0.125	32	0.203	1.8	2.11	24
Haplic chernozems	0.135	30	0.165	1.4	2.11	28
Eutric chernozems	0.145	28	0.150	1.2	2.11	32
Eutric vertisols	0.150	29	0.113	1.1	1.97	45
Eutric luvisols	0.110	38	0.065	1.6	1.85	31

In a long-term field trial at the Cotton and Durum Wheat Research Institute - Chirpan on the soil type Eutric vertisols under non-irrigated conditions with potassium fertilization in rates 0, 80, 120 and 160 kg.ha^{-1} at cotton-durum wheat (*Triticum durum* Desf.) were followed the changes of the utilized potassium in the arable layer (0-30 cm) and subsurface (30-60 cm) layer (Panayotova, 2004 a). It was determined that the content in the 0-30 cm layer for the three K levels was respectively the average of 33, 38 mg and 43 mg/100 g soil, i.e. the leached vertisols in the region was characterized with very good supply of available potassium(Table 2). The changes in the subsurface were lower did not differ considerably from the initial ones. The rates used for the fields were adequate for the plants development and nutrition. The cotton with its deep root system can use the present potassium from от arable soil layer. Nikolova and Pchelarova (1989) also underline that the plants can utilize 10-40 % of the total amount of potassium from the subsurface soil layer. Maintaining values close to the initial for unfertilized fields demonstrated that the available potassium supply is restored from the reserve (fixed, unavailable) potassium.

The unbalanced and unilateral nitrogen fertilization without application of potassium led to unfavourable ecological consequences, including permanent disturbance of the natural balance between the potassium soil forms (Stoyanov and Ikonomova 1996). For the arable layer the degree of influence for the potassium fertilization was 43.7 %, for the year – 6.5 %, while in the subsurface layer these factors were respectively 24.4 % and 6.0 % of influence (Panayotova, 2009). The coefficient of variance in the arable layer shifted within broader limits (4.62-8.97 %), while in the subsoil the variation was within 4.47-6.7 %.

To determine the need of potassium fertilization not only the content на available soil potassium should be taken under consideration, but also the expected yields, potassium uptake with yield, possible loss of potassium and the need to improve the level of available soil potassium.

Effect of potassium fertilization on cotton yield

The cotton shows good responsiveness to the applied nitrogen, and the efficiency of alone phosphorus and potassium fertilization is lower and in most cases close to unfertilized control. As a result of long-term studies with alone potassium fertilization a tendency was found for an increase of the total seed-cotton yield to 6.4 % as compared to the unfertilized (Table 3).

The high potassium rate - 160 kg/ha did not manifest a depressing influence on the yield despite the good soil supply. The combined NK и NPK fertilization there had a decisive meaning as for

Table 2. Variation of available potassium at long-term fertilization (mg/100 g soil), Chirpan, 2008

Treatment	0 - 30 cm		30 - 60 cm	
	$x \pm m$	CV %	$x \pm m$	CV %
$N_0P_0K_0$	33.2 ± 1.0	8.91	27.9 ± 0.4	4.47
N_{160}	31.4 ± 0.8	6.90	28.6 ± 0.6	6.45
P_{160}	33.3 ± 0.9	7.33	29.5 ± 0.5	5.12
K_{80}	38.1 ± 0.9	6.64	32.0 ± 0.7	6.25
$N_{160}P_{80}$	37.2 ± 0.9	6.99	31.5 ± 0.5	4.80
$P_{160}K_{80}$	37.9 ± 1.0	7.52	32.1 ± 0.7	5.87
$N_{240}P_{240}K_{160}$	43.4 ± 1.4	8.97	33.1 ± 0.6	4.96

Table 3. Effect of potassium fertilization on cotton yield, average for 1988-2007

Fertilization	September harvest		Total yield		
	kg/ha	%	Variation	Mean kg/ha	Mean %
$N_0P_0K_0$	1148[a]	100.0	760 – 2100	1530[a]	100.0
K_{80}	1176[ab]	102.4	820 – 2180	1544[a]	100.9
K_{120}	1194[ab]	104.0	850 - 2220	1580[a]	103.3
K_{160}	1205[ab]	105.0	900 – 2200	1628[a]	106.4
$P_{160}K_{80}$	1238[b]	107.8	1010 – 2280	1641[a]	107.2
$P_{240}K_{80}$	1246[bc]	108.5	1030 – 2320	1654[a]	108.1
$N_{160}K_{80}$	1324[c]	115.3	1120 - 2640	1835[b]	119.9
$N_{160}P_{160}K_{80}$	1316[c]	114.6	1100 – 2750	1872[b]	122.4
$N_{240}K_{80}$	1294[b]	112.7	1060 – 2670	1893[b]	123.7
$N_{240}P_{240}K_{80}$	1288[b]	112.2	1050 - 2550	1887[b]	123.3
$N_{160}P_{160}K_{120}$	1339[c]	116.6	1160 – 3090	1916[b]	125.2
$N_{120}P_{120}K_{120}$	1346[c]	117.2	1010 – 3040	1921[b]	147.8
$N_{160}P_{160}K_{160}$	1328[c]	115.7	1210 – 2880	1940[b]	126.8
$N_{240}P_{24}K_{160}$	1286[b]	112.0	1090 - 2560	1909[b]	124.8
LSD, P< 0,05	82	7.14	-	167	10.92
LSD, P< 0,01	109	9.49	-	189	12.35
LSD, P< 0,001	143	12.46	-	196	12.56

*Differences among the values are statistically significant at P<0,05 if have not equal letters

the cotton earliness expressed in the September yield, as well as in the total yield. The degree of influence by the year condition was much higher in comparison with the potassium fertilization. The potassium use efficiency was 0.18-0.61 kg seed-cotton and increased with the increasing nutrient level (Table 4).

Effect of different potassium sources on cotton yield

At the comparative effectiveness of potassium fertilizers in different rates, applied once in the autumn and fractional for Leached Vertisols for the period 1996-1998, essential differences were not observed in the efficiency of KCl, KNO_3 and $NaKNO_3$ with regard to yield and its structural components – boll weight and number of formed bolls per plant (Table 5). The fraction treatment (80 kg/ha in the autumn and 40 kg/ha during bud formation) was not economically effective at dry conditions.

Table 4. K_2O use efficiency, kg seed cotton

Fertilization	K_{80}	K_{120}	K_{160}
K_2O use efficiency	0.18	0.42	0.61

Quality of the cotton production

The data appointed in Table 6 showed that the potassium fertilization under non-irrigated conditions was not proved effective on the fiber length that ranged on average within 25.4-25.7 mm for a 3-year period. At alone and combined potassium fertilization it was seen the increase of fiber strength up to 9.6 %. With the increasing of the nitrogen level there also increased the metric number that is the index of a finer fiber. The seeds weight showed tendency of increase under NK and NPK fertilization which led to decrease in the lint percentage.

Dry matter production

The total dry matter accumulated in cotton plants with no fertilization was 4630 kg/ha at $N_0P_0K_0$ and there was a tendency of rising with the different rates of potassium (Table 7). With 80 kg K_2O/ha the increase was 2.0 %, and at 160 kgK_2O/ha the dry matter was 5.0 % more. An accretion of 48.4 % was observed at $N_{160}K_{80}$, while at $N_{240}P_{240}K_{160}$ the increase was significant - with 64.8 %. Karev (1986) mentioned that with the increase of the biological yield the economic yield was not increased proportionately. The seed-cotton with respect to total biomass at growing without fertilization was 33.0 %, 32.8-33.5 % was at alone K nutrition and decreased to 25.0 % at $N_{240}P_{240}K_{160}$. Distribution of dry matter within the cotton plants was different in the years, but average for the period it was highest in the stems - 30.4-37.4 % at the different fertilization rates.

Table 5. Effect of different potassium sources on cotton yield, average for 1996-1998

Treatment		Seed cotton yield			Bolls per plant, no	Boll weight, g/boll
Fertilizer	Rate kg/ha	September harvest, kg/ha	Total			
			kg/ha	%		
N_0K_0	-	820	1320	100	2.4	4.4
NH_4NO_3	120	880	1520	115	2.6	4.7
KNO_3	60	890	1460	111	2.7	4.6
KNO_3	120	910	1480	112	2.8	4.8
KNO_3	80+40	890	1490	113	2.6	4.6
$NaKNO_3$	60	900	1430	108	2.5	4.6
$NaKNO_3$	120	920	1480	112	2.6	4.7
$NaKNO_3$	80+40	910	1460	111	2.7	4.6
KCl	60	830	1330	101	2.4	4.4
KCl	120	860	1340	102	2.5	4.4

Table 6. Quality of the cotton production, average for 1996-1998

Treatment	Fiber length, mm	Strength g	Metric number, m	Lint percentage, %	100seeds weight, *g*
$N_0P_0K_0$	25.5	4.18	5837	37.8	9.9
K_{80}	25.4	4.28	5700	37.6	10.0
K_{160}	25.5	4.42	5670	37.7	9.9
$N_{80}K_{160}$	25.7	4.50	5894	37.4	10.2
$N_{240}P_{240}K_{160}$	25.6	4.58	6025	37.0	10.8

Table 7. Dry matter production at the end of cotton vegetation, average for 1999-2002, kg/ha

Treatment		Lint	Seed	Vegetative weight				Total	
				Leaves	Stems	Capsules	Total	kg/ha	%
$N_0P_0K_0$		560[a]	970[a]	1020[a]	1430[a]	650[a]	3100[a]	4630[a]	100
K_{80}		560[a]	980[a]	1040[a]	1450[a]	670[a]	3160[a]	4700[a]	102
K_{120}		580[ab]	1000[a]	1050[a]	1460[a]	680[a]	3190[a]	4770[a]	103
K_{160}		610[b]	1020[a]	1050[a]	1480[a]	700[a]	3230[a]	4860[a]	105
$N_{160}K_{80}$		690[c]	1140[ab]	1710[b]	2400[b]	930[b]	5040[b]	6870[b]	148
$N_{240}P_{240}K_{160}$		720[c]	1190[b]	1850[b]	2850[c]	1020[b]	5720[c]	7630[b]	165
	0,05	41	72	352	213	172	677	769	20.2
LSD,P <	0,01	55	95	467	265	248	809	1030	22.3
	0,001	72	122	513	290	305	1033	1210	26.1

*Differences among the values are statistically significant at P<0,05 if have not equal letters

At N и NP fertilization the differences in the years were smaller compared to $N_0P_0K_0$ and alone P and K fertilization. The coefficient of variance (CV) for vegetative weight was significant higher - 22.8 % in comparison with VC for fiber - 6.5 % and seeds - 6.7 %.

Potassium concentration in cotton plants

The potassium concentration in cotton plants was in direct correlation with the nutrition level (Panayotova, 2004 b). The seeds contained lower potassium percent (1.3-1.4 %) as compared with nitrogen (2.7-3.5 %) and the values were close to phosphorus (1.1-1.4 %). The potassium concentration in the lint was higher in comparison with N and P. The values changed under K influence and reached up to 0.98 % K_2O in fiber, 1.40 % in seeds and 1.92 % in vegetative parts (Table 8). The cotton is well supplied with potassium through the vegetation period. Possible K deficit symptoms may be appointed at using higher yielding and faster maturing cultivars, mainly in irrigated conditions, as well as at increased use of nitrogen

Table 8. Potassium concentration in cotton plant parts at maturity, % of dry matter

Treatment	Leaves	Stems	Burs	Lint	Seeds
$N_0P_0K_0$	1.30	1.16	1.52	0.50	1.30
K_{80}	1.35	1.25	1.74	0.80	1.35
K_{160}	1.42	1.33	1.85	0.95	1.40
$N_{80}K_{80}$	1.34	1.30	1.77	0.84	1.38
$N_{240}P_{240}K_{160}$	1.43	1.38	1.92	0.98	1.40

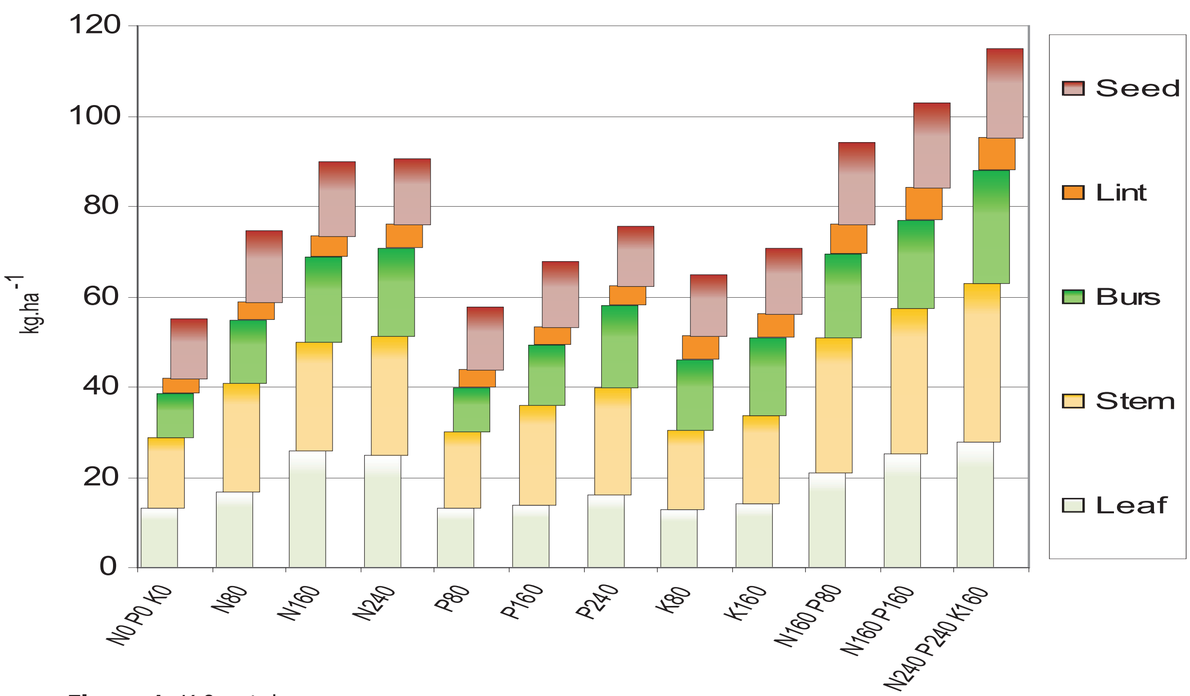

Figure 1. K_20 uptake

(Oosterhuis 1992).

Potassium uptake with cotton yield

K uptake is the main source of information for optimizing the K rates and depends on different factors: meteorological conditions, soil supply, K fertilizing rates, biomass, etc. The K uptake from plants was most intense during the flowering stage. At the end of vegetation with the yield (fiber and seeds) at the different fertilization levels there was an average uptake of 16.4-26.9 kg K_2O/ha per year. At K fertilization the total K uptake was with 17.8-28.2 % higher in comparison with the unfertilized control (55.2 kg K_2O/ha), while at combined NPK fertilization was with more than 108.7 % and reached 115 kg/ha (Figure 1). The values were to greatly influence by the biomass formed (Panayotova and Kostadinova, 2006). Etourneaut (1997) established that the uptake K was 85 to 390 kg/ha at fertilization with 0 to 560 kg/ha at irrigated conditions. With the present technology applied in Bulgaria of chopping and plowing the plant residuals, the K absorbed in the vegetative parts is reapplied in the soil potassium supply.

The expense for 100 kg seed-cotton, together with the additional production was 3.36-4.94 kg K_2O depending on nutrition, soil supply and year conditions. For 100 kg lint this expense reached 13.4 kg K_2O at $N_{240}P_{240}K_{160}$. The increase of the fertilization rate led to increase of the 100 kg expense.

Potassium balance

The application of potassium nutrition maintains the natural and additionally achieved levels of available potassium. The annual crop fertilization forms differential levels of the nutrition regime. The potassium balance, established in stationary field trial at cotton-durum wheat rotation under nonirrigated conditions showed that without fertilization the year deficit was 51.9 kg/ha (Table 9). The balance is optimal under fertilization with 70 kg/ha. Although the soil is well supplied with potassium, the difference in the balance when applying moderate K rates (140 kg/ha) was not big – 43.5 kg/ha per year. The consequence от low and moderate potassium fertilization can remain obscure probably due to the potassium turning into a not readily soluble available form. High positive correlation between potassium balance (y) and content of available K in the soil (x) was established: $y= -46.66+1.18x$ at $r = 0.998^{**}$. Applied potassium fertilizer was used at different rates from 22.9 to 31.8 % and held middle position between N and phosphorus utilization. The coefficients ranged in the years in dependence with the cotton development, soil supply and environments. In order to increase this coefficient and to maintain the soil fertility what it is necessary is periodical potassium fertilization at low rates.

Table 9. Potassium balance for cotton-durum wheat crop rotation, kg/ha

Fertilization level	Input K_2O			K_2O - removal	Balance
	With fertilizers	With seeds	Total		
$N_0P_0K_0$	-	0.2	0.2	52.1	-51.9
K_{70} (low)	70	0.2	70.2	68.1	+2.1
K_{140} (moderate)	140	0.2	140.2	96.7	+43.5

Conclusion

The potassium nutrition is a factor to stabilize the potential productive opportunities of the cotton. The cotton realized average seed-cotton yield from 1530 kg/ha ($N_0P_0K_0$) to 1909 kg/ha ($N_{240}P_{240}K_{160}$) and uptake 55-115 kg K_2O/ha. The expense for 100 kg seed-cotton, together with additional production in the studied period was 3.36-4.94 kg. For 100 kg lint this expense reached 13.4 kg K_2O at $N_{240}P_{240}K_{160}$. The potassium use efficiency was 0.18-0.61 kg seed-cotton. The K concentration, removal and expense for 100 kg seed-cotton and lint increased with the increase of fertilizer rates. The potassium influence on quality parameters was insignificant.

The soils where cotton is grown in Bulgaria are well supplied with potassium and no symptoms of shortage were established. On the grounds of the established potassium nutrition requirements for the soil type Eutric Vertisols a balancing potassium fertilization is necessary in rates 60-70 kg/ha, complied with the results from soil analyses and plant diagnostics. These norms are effective and ecological.

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Papers shall be submitted at the editorial office typed on standard typing pages (A4, 30 lines per page, 62 characters per line). The editors recommend up to 15 pages for full research paper (including abstract references, tables, figures and other appendices)

The manuscript should be structured as follows: Title, Names of authors and affiliation address, Abstract, List of keywords, Introduction, Material and methods, Results, Discussion, Conclusion, Acknowledgements (if any), References, Tables, Figures.

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Abstract should be not more than 350 words. It should be clearly stated what new findings have been made in the course of research. Abbreviations and references to authors are inadmissible in the summary. It should be understandable without having read the paper and should be in one paragraph.

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Mauff G, Pulverer G, Operkuch W, Hummel K and Hidden C, 1995. C3-variants and diverse phenotypes of unconverted and converted C3. In: Provides of the Biological Fluids (ed. H. Peters), vol. 22, 143-165, Pergamon Press. Oxford, UK.

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AGRICULTURAL
SCIENCE AND TECHNOLOGY

Volume 2, Number 2
June 2010

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