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EFFECT OF FERTILIZATION ON PHOSPHORUS UPTAKE IN COTTON

Galia Panayotova
Trakia University, Faculty of Agriculture, Department of Plant Production, Bulgaria
Email: galia_panayotova@abv.bg

Svetla Kostadinova
Agricultural University, Faculty of Agronomy, Department of Agrochemistry and Soil Science, Bulgaria

Abstract

The aim of this research was to studythe effects of nitrogen and phosphorus fertilization on concentration and uptake of phosphorus in cotton (*G. hirsutum* L.), grown during 2012-2014 on *Pellic Vertisols* soil type in Chirpan, Bulgaria in crop-rotation with durum wheat under non-irrigated conditions. The experimental design was a randomized complete block with four replications. Single and combined nitrogen as NH_4NO_3 in rates 0; 80; 120 and 160 kg.ha^{-1} and phosphorus in rates 0; 80 and 120 kg.ha^{-1} were tested. It was established that fertilization with $N_{120}P_{80}$led to the highest economic effective yield – 1.82 t.ha^{-1}, by 37.8% above the unfertilized. An alone phosphorous fertilization was not an efficient agronomic activity. Fertilization with P_{80} and P_{120} increases the phosphorus concentration in cotton plants. In bud formation an extremely high phosphorus content of 1.06% is reported at moderate levels $N_{120}P_{120}$ and the average phosphorus content is 0.82%. The P concentration in flowering stage is in the range of 0.67 (unfertilized) to 0.87% (P_{120} and $N_{80}P_{120}$). The phosphorus concentration decreases in maturity - average 0.53%. The phosphorus uptake depends on both the dry matter accumulation and the P concentration. The uptake of phosphorus averaged from 18.3 kg.ha^{-1} ($N_0P_0K_0$) to 35.9-40.0 kg.ha^{-1} at high values of NP fertilization. The uptake was 24.5-25.6 kg.ha^{-1} at alone P rates. Nitrogen has a stimulating influence on the phosphorus utilization. At combined NP fertilization the P uptake increases significantly and at $N_{160}P_{120}$ reaches 40.0 kg.ha^{-1}. P concentration and uptake went up with the increase of the phosphorus rate.
Key words: Phosphorus, concentration, uptake, cotton, fertilization.

1. Introduction

Knowledge of phosphorus content in relation to plant development and yield is valuable and useful for various branches of the agricultural practice. For the producer it provides information for making management decisions relative to timing and rates of NPK application to avoid occurrence of deficiency. In research it is important to identify the development stage at sampling when evaluating experiments with data from tissue analysis, and also when comparing treatment effects, since changes in concentration of NPK occur as plants mature.

Variable responsiveness of cotton to phosphorus fertilization is established in different countries ofthe World.In the United States, P application produced significantly positive response to seed cotton yield on the sandy soils whereas little or no response was obtained on the fertile alluvium (Nelson, 1980). In Israel, sodium bicarbonate extractable phosphorus isrecommended as an index for fertilization of cotton crop and if more than 12 mg.kg^{-1}available P is present in the soil, no fertilizer is added (Halevy, 1976). Bronson et al., (2003) reported that phosphorus fertilizer did not affect lint yields at Lamesa.

More and Agale (1993) indicated that seed cotton and dry matter yield increased with increasing levels of P up to 50 kg P_2O_5 ha^{-1}. Uptake of P ranged from 27.2 to 32.9 kg ha^{-1}. There was gradual increase in P uptake with increasing levels of P up to 75 kg P_2O_5 ha^{-1}. The P balance at 25 kg P_2O_5 ha^{-1} rate was negative.

The nitrogen utilization is closely related to the phosphor nutrition. P significantly enhanced cropgrowth, N and K uptake, total chlorophyll concentration and dry matter yield of cotton plant (Sawan et al., 2008). Deshpande and Lakhdive (1994) found that Papplication (19-22 kg ha^{-1}) increased P uptake and content in leaf, stemand reproductive part like seed. Acording to Leffler (1986) and Bassett et al. (1970) the phosphorus fertilization increased dry matter production and nutrient uptake.

According to some authors the cotton varieties manifest specific nutrient requirements (Karamanidis et al., 2004; Fritschi et al., 2003; Clement-Bailey and Gwathmey, 2008) while according to others (Kostadinova & Panayotova, 2003; Mullins and Burmester, 1990; Panayotova et al., 2007) the differences in the level of mineral nutritionof genotypes with close origin are insignificant. The variety specificity to uptake of nutrition elements in the cotton organs was established by Meredith & Wells (1989) and Makhdum et al. (2001), but Mullins & Burmester (1990) report that the concentrationanduptakeof macroelements are not significantly influenced by the variety.

The aim of this research was to study the effects of nitrogen and phosphorus fertilization on concentration and uptake of phosphorus in cotton (*G. hirsutum* L.), grown during 2012-2014 in crop-rotation with durum wheat under non-irrigated conditions in theregionofCentral South Bulgaria.

2. Material and Methods

The experiment was carried out on the field of the Field Crops Institute, Chirpan, situated in a major cotton-growing region of Bulgaria during 2012-2014. The cotton (*G. hirsutum* L.) cultivar Darmi was grown in double crop-rotation with durum wheat under non-irrigated conditions. The experimental design was a randomized complete block with four replications. Individual plots consisted of six 2.40-m rows spaced 0.60 m apart with a net plot size of 10 m^2. Single and combination of N and P_2O_5 fertilizers were tested. The nitrogen rates were 0; 80; 120 and 160 kg.ha^{-1} and of phosphorus – 0; 80 and 120 kg.ha^{-1}. The source of the N was ammonium nitrate, of P_2O_5 – triple superphosphate. Cotton seeds were sown within 20-30 April. The plant population reached as much as 160 000 plants ha^{-1}, approximately. Defoliants were not applied. The harvest was made by hand.

The total seed-cotton yield (t.ha^{-1}) and yield of the total biomass (t.ha^{-1}) were determined. Plant material was dried at 60°C, weighted and sieved. The P_2O_5 content in plant parts (% of dry matter) was analyzed colorimetrically. P_2O_5 uptake (kg.ha^{-1}) was the product of dry matter yield (kg.ha^{-1}) and concentration (%). Analysis of variance (ANOVA) was performed to evaluate differences and interaction among the nitrogen rates, phosphorus rates and years.

The studied years were with different meteorological conditions during the vegetation period (May-October). Regarding temperature and rainfall during cotton vegetation, the studied years were characterized as follows: 2012 was very warm and dry, with insufficient precipitation during the critical stages of cotton development flowering and bolls formation; 2013 was characterized as moderately warm and moderately dry; and 2014 was moderately warm and very wet.

The soil type at the region was *Pellic Vertisols* (FAO), defined by the sandy-clay composition, with high humidity capacity and small water-permeability. The soil in the field was with neutral soil reaction in the 0-60 cm soil layer, medium supplied with organic matter, moderately N provided, with low content of mobile P_2O_5 and well supplied with available K_2O (**Table 1**).

Table 1. Agrochemical Properties of the Soil, Chirpan

Parameters	**Depth, cm**	
	0-30	**30-60**
pH_{KCl}	6.7	6.2
Humus, %	2.80	2.55
Total N, %	0.100	0.090
Total Nmin, kg.ha^{-1}	97	83
Available P_2O_5, mg.kg^{-1}	51	39
Exchangeable K_2O, mg.kg^{-1}	230	160

3. Results and Discussion

The results showed that fertilization had a good effect on seed-cottonyieldwith an average yield of 1.62 t.ha^{-1} (**Figure 1**).Without fertilization the average seed-cotton yield was 1.32 t.ha^{-1}.The studied alone N fertilization showedsignificant increase in the seed-cotton yield up to N_{120} – an average of 1.76 t.ha^{-1}, by 32.9 % above the unfertilized control.The high rate of N_{160} decreased the yield by 2.4 % compared to the yield obtained from the moderate level of N_{120}. Average good yield was reported at N_{80} – 1.67 t.ha^{-1}, and at this low rate in2014 cultivar Darmi had a very good yield - 2.46 t.ha^{-1}. The seed-cotton yield increased most under combined fertilization $N_{120\text{-}160}P_{80\text{-}120}$ - 26.6-37.8 % more than the unfertilized. In 2012 and 2013 the low yields were due to the higher temperatures during the vegetation period– 383 and 259^{o}C more than the average values, respectively, as well as due to the long spring-summer drought, which led to shedding of budsand blossoms and impeded the proper nourishment of the bolls.

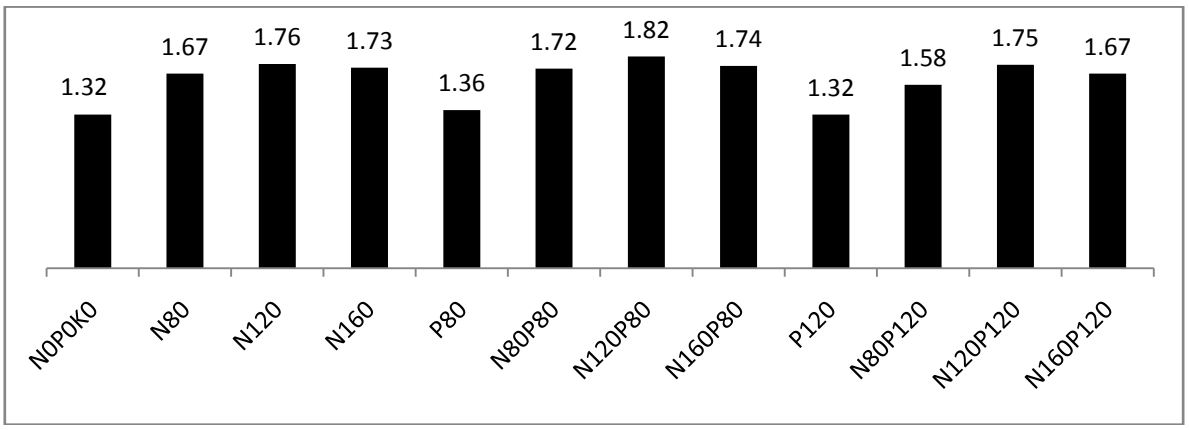
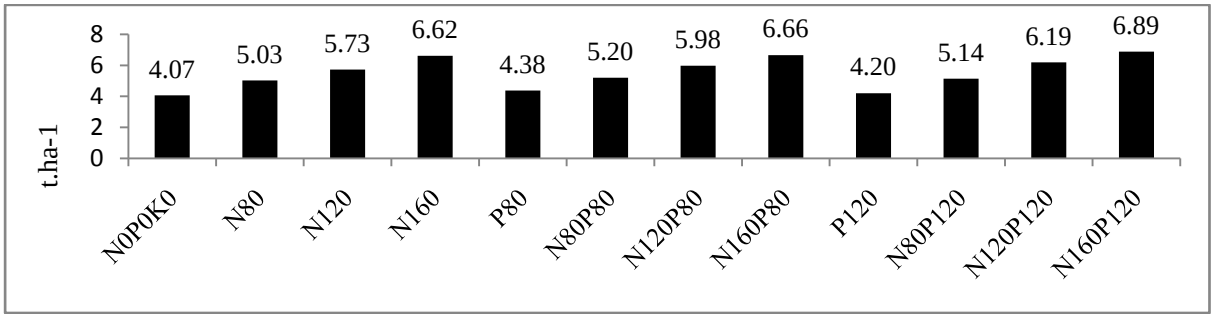


Figure1. Mean Effect of Fertilization on Total Seed-Cotton Yield, t.ha^{-1}
GD 5 %; 1 %; 0.1%= 0.28; 0.36; 0.47

The amount of dry matter including seed cotton yield, formed leaves, stems and bolls in maturity average for the period was 5.51t.ha^{-1}.Unfertilized plants formed 4.07 t.ha^{-1}of dry matter. At fertilization with$N_{80}N_{120}$ and N_{160} the total dry matter at the maturity exceeded the unfertilized by 24;41and 63%, respectively. Single phosphorus fertilization contributed to the increase of dry matter by 7.6% at P_{80} and by 3.4% at P_{120}. Combined NP fertilization had a proven effect on dry matter yield. After fertilization with $N_{80}P_{80}$the total dry biomass increased and it was 5.2t.ha^{-1} average for the period, by 27.8% above the unfertilized. Increasing the combined fertilization rates also led to an increase of cotton dry matter. $N_{160}P_{80}$formed 6.66 t.ha^{-1}biomass, 63.8% more than the control. Average for the period the highest result was reported for high combined fertilization at rate $N_{160}P_{120}$ –69.4% over the unfertilized(**Figure 2**).



GD 5 %; 1 %; 0.1%=0.63; 0.86; 1.16

Figure 2. Effect of Fertilization on the Total Dry Biomass of Cotton in Maturity, t.ha^{-1}

It has been established from previous studies that the fiber contains minimal amounts of phosphorus and the values in the vegetative mass are generally low (0.14-0.28%) (Panayotova, 1999). Seeds are relatively well-supplied with phosphorus (1.1-1.40%). Singh et al. (2006) reported that leaf fresh mass and leaf area per plant were positively related to the leaf P %, which increased with increasing P supply.

During the three years of the cotton growing stages, fertilization with P_{80} and P_{120} increases the phosphorus content in the plants (**Figure 3)**. The phosphorus concentration went up with the increase of the phosphorus rate.

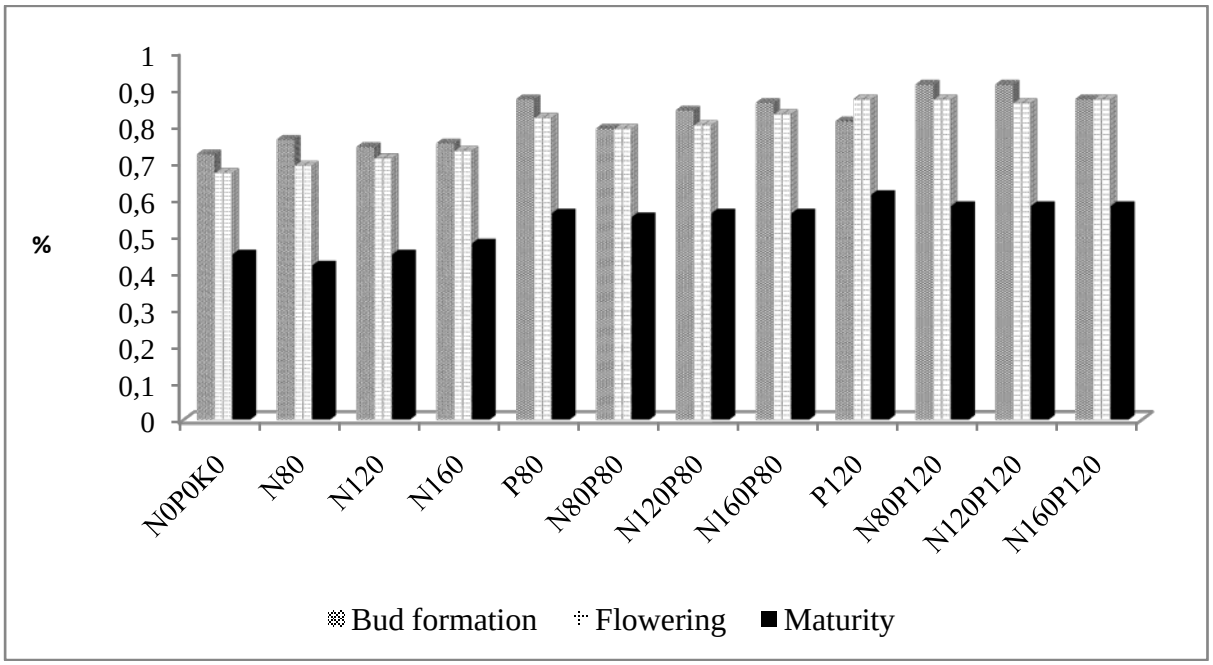


Figure 3. Phosphorus Concentration in Cotton Plants by Development Phases, %

Inbud formation stage independent phosphorus fertilization results in 20.8-25.0% higher phosphorus concentration in plants.At N fertilization there is a tendency to increase phosphorus amounts to 5.6 % according to unfertilized, probably related to better growth and development of plants and root system and the ability to better utilization of available soil phosphorus. At combined NP fertilization the phosphorus content depends on the phosphorus rate and reaches 0.91% at P_{120}.An extremely high phosphorus content of 1.06% in bud formation is reported at moderate levels of combined fertilization $N_{120}P_{120}$. At this stage the average phosphorus content for the period is 0.82%, and in 2012 the concentrationis the highest - 0.90%, mainly due to the higher temperatures in May and June. The average phosphorus values decrease at all N levels and at P_{80} rateduring the later stages of the vegetation. In the flowering stageonly at $P_{120}$the phosphorus content is higher than the bud formation. The average phosphorus content is in the range of 0.67 (unfertilized) to 0.87% (P_{120} and $N_{80}P_{120}$). The influence of yearsis strong - the concentration is from 0.68% in 2012 to 0.99% in 2013 with better water permeability.

Dorahy et al. (2008) indicated that phosphorus fertilizer application only increased P concentration in the plants during leaf expansion, but had no effect on biomass production, P uptake at later growth stages sampled, or lint yield. This is confirmed in our study.The phosphorus concentration decreases in maturity and the plants contain average 0.53% phosphorus, in the range of 0.42 (N_{80}) to 0.61% (P_{120}).The maximum values in maturityare in 2012 - an average of 0.68%, nearly twice higheraccording to average concentration in 2013. Only differences in bud formating are prove.

The phosphorus uptakein maturity depends on both the dry matter accumulation and the P concentration. The uptake of phosphorus in the study averaged from 18.3 $kg.ha^{-1}$ ($N_0P_0K_0$) to 35.9-40.0 $kg.ha^{-1}$ at high values of NP fertilization. P uptake went up with the increase of the phosphorus rate (**Figure 4)**. The lower biomass values conditioned the smaller amounts of P uptake and henceforth

the higher residual amounts of available P in soil. Not always the P uptake corresponded to the obtained cotton yield. Phosphorus uptake continued to plant maturity, with more being allocated to seed at the expense of burs and leaves. Phosphorus levels should be high enough and plants should be vigorous enough to support P uptake and translocation from vegetative organs to fruiting structures as cotton bolls mature.

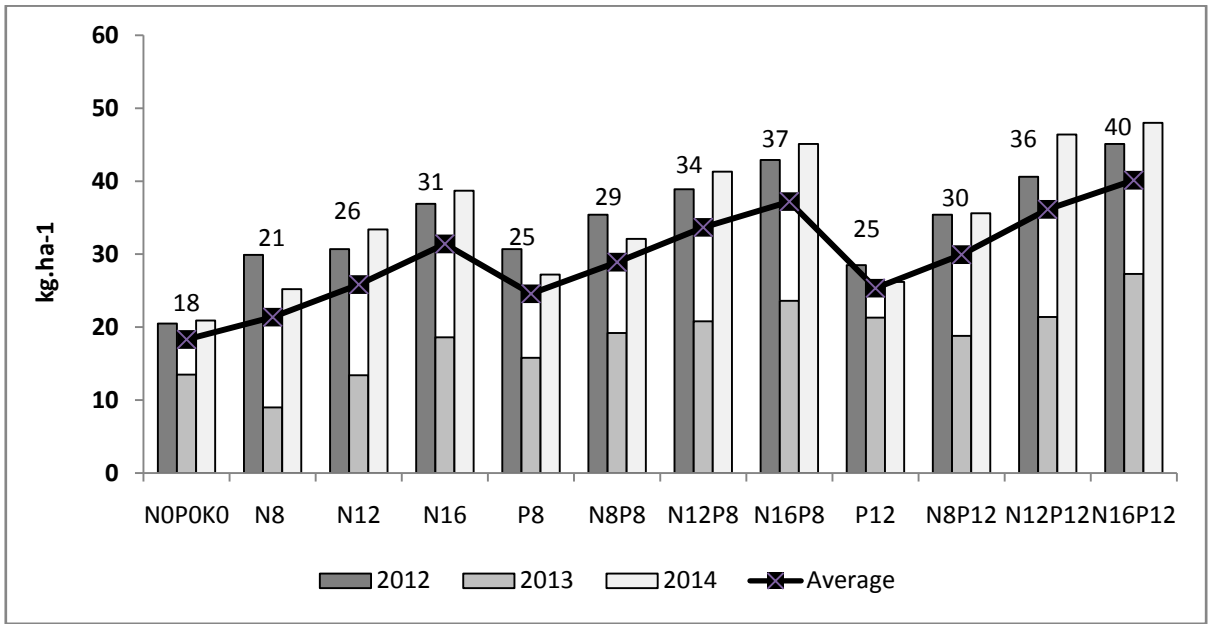


Figure 4. Phosphorus uptake by Cotton Plants, kg.ha^{-1}

At two alone phosphorous rates the annual average uptake was 24.5 and 25.6 kg.ha^{-1}, rising by 33.9 and 39.9% respectively to the control. In 2012 the plants absorb larger amounts of phosphorus – 30.7 and 28.5 kg.ha^{-1}, respectively at these fertilizer rates.The higher value at the lower rate P_{80} is associated with higher total biomass yield and good soil supply with mobile phosphates. Bassett et al. (1970), Deshpande and Lakhdive (1994), Leffler (1986) and others also indicate that phosphorous fertilization increases the uptake of phosphorus and its content in the vegetative and reproductive parts of the plant.

Nitrogen has a stimulating influence on the phosphorus utilization from cotton plants. At alone Nfertilization the absorbed phosphorus is from 21.2 kg.ha^{-1}(N_{80}) to 31.8 kg.ha^{-1} at N_{160}. At combined NP fertilization phosphorus uptake increasessignificantlyand at $N_{160}P_{120}$ reaches 40.0 kg.ha^{-1}.

The uptake of phosphorus average for the period was 29.2 kg.ha^{-1}. In 2014 it is higher- 35.0 kg.ha^{-1}, which we would explain with the good weather conditions during the year and the higher above ground biomass (6.5 t.ha^{-1}). During this year the highest phosphorus uptake - 48.0 kg.ha^{-1}was reportedat the highest combined fertilization $N_{120}P_{120}$.

4. Conclusions

The results showed that phosphorus fertilization exerts a favourable influence on cotton plants. The phosphorous application to the Bulgarian cotton cultivarDarmi increased seed-cotton yield, concentration and P uptake.

Under the influence of N fertilization the total seed-cotton yieldincreasedby 26.6 (N_{80}) to 32.9% (N_{120}) compared to the unfertilized (1.32t.ha^{-1}),and at P fertilization – up to 2.9% at P_{80}. Fertilization with $N_{120}P_{80}$led to the highest economic effectiveyield –37.8% above the unfertilized.An alone phosphorous fertilization was not an efficient agronomic activity.

The total dry biomass yield in maturity stage was an average 5.51 t.ha^{-1}. At single fertilization with N_{80}, N_{120} and $N_{160}$the total dry matter in the maturity was more than the unfertilized (4.07 t.ha^{-1})by

24.0, 40.8 and 62.8%, respectively. Single phosphorus fertilization increased the biomass by 7.6% at $P_{80}$and by 3.4% at P_{120}.Thebiomasswas highest at combined fertilization $N_{160}P_{120}$.

Fertilization with P_{80} and P_{120} increases the phosphorus concentrationin the plants.In bud formation an extremely high phosphorus content of 1.06% is reported at moderate levels $N_{120}P_{120}$ and the average phosphorus content is 0.82%.The phosphorus concentration in flowering stage is in the range of 0.67 (unfertilized) to 0.87% (P_{120} and $N_{80}P_{120}$). The phosphorus concentration decreases in maturity and the plants contain average 0.53% phosphorus.

The phosphorus uptake depends on both the dry matter accumulation and the P concentration. The uptake of phosphorus averaged from 18.3 kg.ha^{-1} ($N_0P_0K_0$) to 35.9-40.0 kg.ha^{-1} at high values of NP fertilization. Atalone P rates the uptake was 24.5-25.6 kg.ha^{-1}. At combined NP fertilization the P uptake increasessignificantlyand at $N_{160}P_{120}$ reaches 40.0 kg.ha^{-1}.

Such information would enhance nutrient management strategies and may be used for cotton development/yield models.

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