RESPONSES OF FLUE-CURED TOBACCO TO THE FERTILIZATION OF PHOSPHORUS ON SANDY SOILS IN SOUTH AFRICA.

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SUMMARY

High soil-test values for available phosphorus often seem to be ignored by growers and large amounts of phosphates are generally applied. This causes much concern for it unnecessarily increases costs and also potentially raises the possibility of polluting natural recourses. The necessity to persuade growers to adapt to the fertilizer guideline for phosphorus led to a series of on-farm demonstration plots to evaluate the response of flue-cured tobacco to levels of applied phosphorus. Levels of P were applied directly after planting in hand-made furrows on both sides of ridges by using mono ammonium phosphate together with proportional amounts of limestone ammonium nitrate for the equalization of nitrogen level. Other nutrients, and further top dressings of nitrogen, were applied and managed by the individual growers. Four mature plants from each treatment were sampled at 12-13 weeks after planting and each plant was sub divided into seven top leaves, seven middle leaves, the remaining bottom leaves and the stalk. All samples were rinsed with de-ionized water, dried at 60^0C and weighed for the determination of dry mass. The samples were then milled and analyzed for nutrient content. Increased rates of applied phosphorus on sandy soils with good soil reaction and Bray 2 extractable P > 40mg P kg^{-1} reduced yield, drastically lowered the concentration of zinc and copper to levels of less than sufficiency, and increased the occurrence of necrotic leaf diseases. It was also observed that sub-soil acidity, associated with a high level of extractable aluminium, resulted in no response to the fertilization of phosphorus.

INTRODUCTION

The guideline for the fertilization of phosphorus for flue-cured tobacco is based on the Bray 2 extractable phosphorus and the expectation is that a norm of roughly 25 mg P kg^{-1}, for a sandy soil with good soil reaction, already signifies enough phosphorus to meet the nutrient requirement of a flue-cured tobacco crop. It is, however, still necessary to maintain and further improve the phosphorus status of soils, and in cases where test results show values of 25 to 30 mg P kg^{-1} a maximum of 45 kg P ha^{-1} is recommended. When the available phosphorus is found to be 31 to 40 mg P kg^{-1} it is only deemed necessary to maintain the good status by recommending roughly 20 kg P ha^{-1}. Bray 2 extractable phosphorus values of higher than 40 mg P kg^{-1} are indicative of a soil that has a history of phosphate fertilization and in such cases zero P is recommended. However, growers of flue-cured tobacco in South Africa generally believe that the fertilization of phosphorus, not withstanding the phosphorus status of the soil, will always be beneficial. This causes much concern for it unnecessarily increases costs and also potentially raises the possibility of polluting natural recourses. The necessity to persuade growers to adapt to the fertilizer guideline for phosphorus led to a series of mostly non-statistical on-farm demonstration plots to evaluate the response of flue-cured tobacco to levels of applied phosphorus.

MATERIAL AND METHODS

Demonstration trials were conducted on sandy soils during the 2005/2006 and 2007/2008 seasons at Naboomspruit, Vaalwater and Alma, with Bray 2 extractable P soil-test values of respectively 45, 36 and 26 mg P kg^{-1}. Levels of P were applied directly after planting in hand-made furrows on both sides of ridges by using mono ammonium phosphate together with proportional amounts of

limestone ammonium nitrate for the equalization of nitrogen level. Other nutrients, and further top dressings of nitrogen, were applied and managed by the individual growers. At Naboomspruit and Alma four fully-grown plants from each treatment were sampled and each plant was sub- divided into seven top leaves, seven middle leaves, the remaining bottom leaves and the stalk. At Naboomspruit the tobacco grew at normal rate and the fully grown plants were sampled at 12-13 weeks after planting. At Alma, however, very slow growth of the tobacco was noted as from roughly the sixth week after planting and the fully-grown stage was reached as late as 19 weeks after planting. At eleven weeks after planting the trial at Vaalwater was badly hail damaged and from each treatment four samples, only representing the top leaves, were sampled. All samples were rinsed with de-ionized water, dried at 60^0C and weighed for the determination of dry mass. The samples were then milled and analyzed for nutrient content. All data were analysed statistically and significant differences were calculated at the $p = 0.05$ test level.

RESULTS AND DISCUSSION

Naboomspruit - 2005/2006

The dry mass of the leaves, stalks and total plant (Table 1), was reduced by the fertilization of phosphorus. The phosphorus concentration of the plant parts were not affected by the treatments. However, due to the negative effect that the increased rate of phosphorus had on yield, it is shown in Table 2 that the increased rate of phosphorus resulted in a decrease in the uptake of phosphorus.

Results in Tables 3 and 4, show that the concentrations of copper and zinc were reduced by the fertilization of phosphorus to levels of less than sufficiency. Due to the negative effect that the increased rate of phosphorus had on yield, results in these tables also show how the increased rate of applied phosphorus negatively affected the uptake of both copper and zinc.

A rating scale of 1-5 was used for the incidence of necrotic leaf diseases and was 1.5, 2.5 and 4.5 for the zero, 22 and 44 kg P ha^{-1} respectively.

Vaalwater - 2007/2008

The nutrient concentrations of the hail-damaged top leaves (Table 5), show the highest concentration of P where no phosphorus was applied. The high phosphorus concentrations obtained indicate that there was no need for the fertilization of P. This is attributed to an extractable P (Bray 2) soil-test value of 36 mg kg^{-1} and a good soil reaction as measured by the pH (saturated water paste) of 6.19 and 5.87, for the top- and sub soil respectfully. It is, however, noted that in all cases where phosphorus was applied, the copper concentration was significantly lower than where no phosphorus was applied. These data are also graphically shown in Figure 1. This result is indicative of the fact that the fertilization of phosphorus, in cases where not necessary, can be disadvantageous by inducing a possible micro-element deficiency.

Alma - 2007/2008

The dry mass of the leaves, stalks and total plant (Table 6) show an average potential leaf yield of 3686 kg ha^{-1} and an above-average yield of 3856 kg ha^{-1} where zero P was applied. These reasonably good yields were found in spite of the slow growth that was noted as from six weeks after planting and a fully-grown stage that was reached as late as 19 weeks after planting. The reason for the slow growth experienced, was likely due to a sub-soil pH (saturated water paste) of 4.47 with a high level of aluminium saturation (23.5%). It is speculated that sub-soil acidity, associated with a high level of extractable aluminium, resulted in no response to the fertilization of phosphorus. This assumption is supported by the sub-optimal P-concentration of the plant parts of fully grown tobacco shown in Table 7.

CONCLUSIONS.

The fertilization of phosphorus on sandy soils with good soil reaction and Bray 2 extractable P > 40mg P kg^{-1} is questioned. Such practices seem to reduce yield, drastically lower the concentration of zinc and copper to levels of less than sufficiency, and in certain cases increase the occurrence of necrotic leaf diseases. The non-response of applied phosphorus where sub-soil acidity is associated with a high level of extractable aluminium has created new challenges and points to the necessity of ameliorating the sub-soil by incorporating lime to a deeper depth.

Table 1. Dry mass (g/plant) and (kg/ha)* of plant parts of fully grown flue-cured tobacco plants at three levels of phosphorus at Naboomspruit – 2005/2006 season.

Weeks after planting: (stage)	Plant part	Treatment						Average	
		0 kg P/ha		22kg P/ha		44 kg P/ha			
		g/plant	kg/ha	g/plant	kg/ha	g/plant	kg/ha	g/plant	kg/ha
13 Weeks (fully grown)	Top leaves	113.3	1880	107.3	1780	107.0	1776	109.2	1812
	Middle leaves	75.0	1245	66.3	1100	64.3	1067	68.5	1137
	Bottom leaves	59.5	988	48.8	809	39.5	656	49.3	818
	Stalk	139.0	*2307*	131.3	*2179*	120.8	*2004*	130.3	2164
	Total plant	*386.8*	*6420*	*353.5*	*5868*	*331.5*	*5503*	357.3	5930
Leaf mass		247.8	4113	222.3	3689	210.8	3498	226.9	3767
Stalk mass		139.0	2307	131.3	2179	120.8	2004	130.3	2164
Total plant mass		***387***	***6420***	***354***	***5868***	***332***	***5503***	**357**	***5930***
Leaves (%)		64	64	63	63	64	64	64	64
Stalks %)		36	36	37	37	36	36	36	36

* Calculated for a plant population of 16 600 ha^{-1}

Table 2. Phosphorus concentration (%) and phosphorus content (kg/ha)* of plant parts of fully-grown flue-cured tobacco plants at three levels of phosphorus at Naboomspruit – 2005/2006 season.

Weeks after planting: (stage)	Plant part	Treatment						Average	
		0 kg P/ha		22kg P/ha		44 kg P/ha			
		P% (g/100g)	kg P/ha	P% (g/100g)	kg P/ha	P% (g/100g)	kg P/ha	P% (g/100g)	kg P/ha
13 Weeks (fully grown)	Top leaves	0.29	*5.5*	0.28	*5.0*	0.24	*4.3*	0.27	4.9
	Middle leaves	0.29	*3.6*	0.29	*3.2*	0.27	*2.9*	0.28	3.2
	Bottom leaves	0.27	*2.7*	0.29	*2.3*	0.31	*2.0*	0.29	2.3
	Stalk	0.27	*6.2*	0.24	*5.2*	0.23	*4.6*	0.25	5.4
	Total plant		*18.0*		*15.8*		*13.8*		15.8
P in leaves			11.7		10.5		9.2		10.5
P in stalks			6.2		5.2		4.6		5.4
P in whole plants			***18.0***		***15.8***		***13.8***		***15.8***
% in leaves			65		67		67		66
% in Stalks			35		33		33		34

* Calculated for a plant population of 16 600 ha^{-1}

Table 3. Copper concentration (mg/kg) and copper content (g/ha)* of plant parts of fully-grown flue-cured tobacco plants at three levels of phosphorus at Naboomspruit – 2005/2006 season.

Weeks after planting: (stage)	Plant part	Treatment						Average	
		0 kg P/ha		22kg P/ha		44 kg P/ha			
		Cu (mg/kg)	Cu/ha (g)	Cu (mg/kg)	Cu/ha (g)	Cu (mg/kg)	Cu/ha (g)	Cu (mg/kg)	Cu/ha (g)
13 Weeks (fully grown)	Top leaves	10.1	*19.0*	6.8	*12.0*	3.6	*6.4*	6.8	12.5
	Middle leaves	5.6	*7.0*	4.9	*5.4*	4.8	*5.1*	5.1	5.8
	Bottom leaves	6.9	*6.8*	9.1	*7.4*	3.5	*2.3*	6.5	5.5
	Stalk	10.1	*23.4*	7.8	*16.9*	6.8	*13.5*	8.2	17.9
	Total plant		*56.2*		*41.7*		*27.3*		41.7
Cu in leaves			32.8		24.8		13.8		23.8
Cu in stalks			23.4		16.9		13.5		17.9
Cu in whole plants			***56.2***		***41.7***		***27.3***		***41.7***
% in leaves			58		59		51		57
% in Stalks			42		41		49		43

* Calculated for a plant population of 16 600 ha^{-1}

Table 4. Zinc concentration (mg/kg) and zinc content (g/ha)* of plant parts of fully-grown flue-cured tobacco plants at three levels of phosphorus at Naboomspruit – 2005/2006 season.

Weeks after planting: (stage)	Plant part	Treatment						Average	
		0 kg P/ha		22kg P/ha		44 kg P/ha			
		Zn (mg/kg)	Zn/ha (g)	Zn (mg/kg)	Zn/ha (g)	Zn (mg/kg)	Zn/ha (g)	Zn (mg/kg)	Zn/ha (g)
13 Weeks (fully grown)	Top leaves	46.5	*87.4*	38.9	*69.2*	26.4	*46.9*	37.3	67.8
	Middle leaves	33.1	*41.2*	24.9	*27.4*	17.8	*18.9*	25.3	29.2
	Bottom leaves	27.6	*27.3*	17.1	*13.9*	16.1	*10.6*	20.3	17.2
	Stalk	27.5	*63.5*	25.5	*55.6*	22.6	*45.4*	25.2	54.8
	Total plant		*219.4*		*166.0*		*121.7*		169.0
Zn in leaves			156.0		110.4		76.4		114.3
Zn in stalks			63.5		55.6		45.4		54.8
Zn in whole plants			***219.4***		***166.0***		***121.7***		***169.0***
% in leaves			71		67		63		68
% in Stalks			29		33		37		32

* Calculated for a plant population of 16 600 ha^{-1}

Table 5. The chemical composition of hail damaged top leaves at levels of phosphorus at Vaalwater – 2007/2008 season.

Treatment	gram per 100 gram (%)						milligram per kilogram (mg/kg)				
kg P/ha	N	P	K	Ca	Mg	Cl	Fe	Cu	Zn	Mn	B
0	3.48	0.55	2.49	1.41	0.61	0.96	120	14.6	77.0	128	16.8
20	4.01	0.43	2.50	1.52	0.64	0.64	124	6.3	66.1	165	16.5
40	4.03	0.51	2.80	2.03	0.78	0.72	124	5.8	73.7	207	16.1
60	3.77	0.51	2.65	1.88	0.70	0.67	125	4.5	66.5	180	16.1
80	3.48	0.50	2.79	1.85	0.56	0.78	152	5.5	38.7	129	21.3
38*	3.62	0.50	2.58	2.08	0.63	0.67	148	5.5	47.5	134	21.3
Average	3.73	0.50	2.63	1.79	0.65	0.74	132	7.0	61.6	157	18.0
CV (%)	6.6	8.0	6.0	15.7	17.8	12.1	10.6	16.4	14.6	18.8	11.1
LSD (p=0.05) Tukey	Ns	Ns	Ns	Ns	Ns	0.20	Ns	2.6	20.7	Ns	Ns

*: Commercial level

(Ns): Non significant

Figure 1. Copper concentration of hail-damaged top leaves at levels of P - Vaalwater - 2007/2008 season.

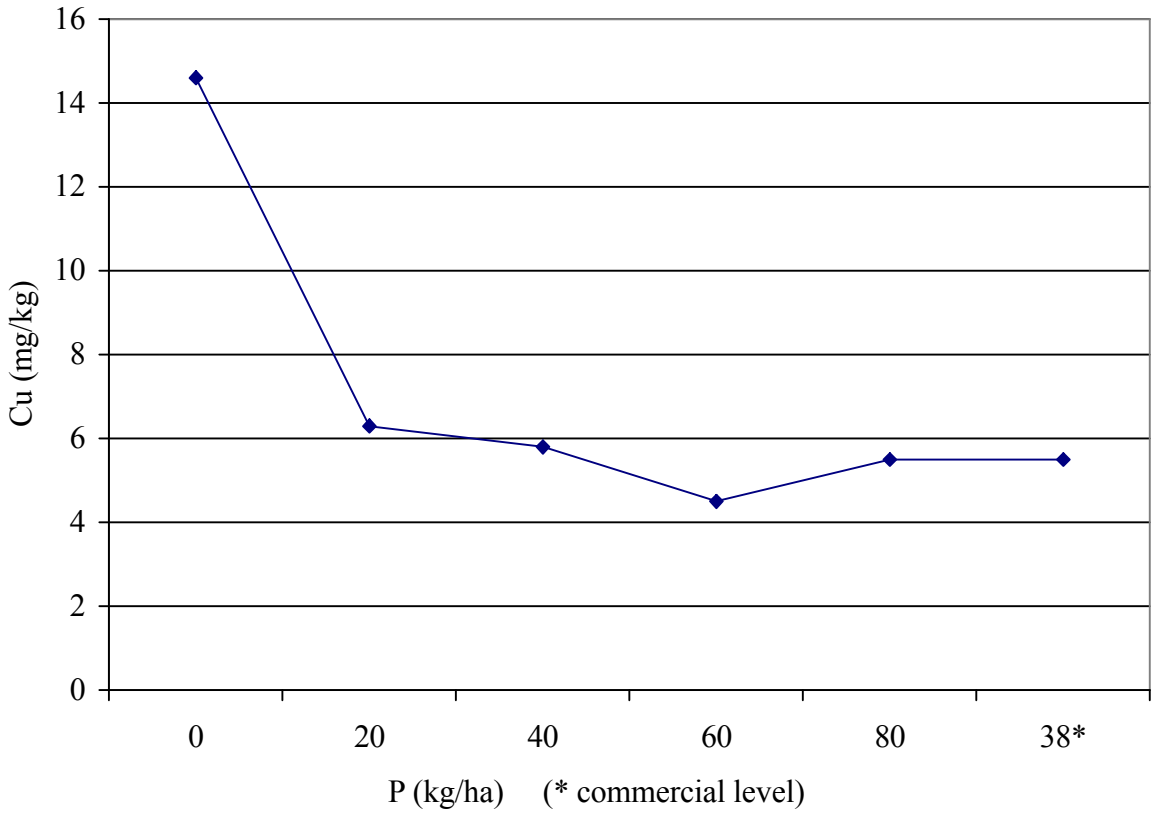

Table 6. Dry mass (kg/ha)* of plant parts of fully grown flue-cured tobacco plants at six levels of phosphorus at Alma – 2007/2008 season.

Weeks after planting: (stage)	Plant part	Treatment (kg P/ha)						Average
		0	20	40	60	80	36**	
		Dry mass (kg/ha)						
19 weeks (fully grown)	Top leaves	1121	1038	1320	1540	1336	1473	1304
	Middle leaves	1328	1154	1523	1311	1287	1208	1302
	Bottom leaves	1408	950	1013	1266	930	913	1080
	Stalk	1664	1378	1585	1768	1444	1577	1569
Leaf mass		3856	3142	3855	4117	3552	3594	3686
Stalk mass		1664	1378	1585	1768	1444	1577	1569
Total plant mass		5520	4519	5441	5885	4997	5171	5255
Leaves (%)		70	70	71	70	71	70	70
Stalks %)		30	30	29	30	29	30	30

*: Calculated for a plant population of 16 600 ha^{-1} **: Commercial level

Table 7. Phosphorus concentration (%) of plant parts of fully grown flue-cured tobacco plants at six levels of phosphorus at Alma – 2007/2008 season.

Weeks after planting: (stage)	Plant part	Treatment (kg P/ha)						Average
		0	20	40	60	80	36**	
		Dry mass (kg/ha)						
19 weeks (fully grown)	Top leaves	0.18	0.18	0.19	0.19	0.19	0.19	0.19
	Middle leaves	0.18	0.19	0.18	0.18	0.19	0.19	0.19
	Bottom leaves	0.20	0.20	0.22	0.18	0.21	0.25	0.21
	Stalk	0.17	0.16	0.17	0.18	0.18	0.17	0.17

**: Commercial level