XA9642757

PERFORMANCE OF *ACACIA TORTILIS*, *PROSOPIS JULIFLORA* AND *CASUARINA EQUISETIFOLIA* PROVENANCES IN SOILS LOW IN PHOSPHORUS

XA9642757

D.O. NYAMAI, P.O. JUMA
Agroforestry Research Programme,
Kenya Forestry Research Institute,
Nairobi, Kenya

Abstract

PERFORMANCE OF *ACACIA TORTILIS*, *PROSOPIS JULIFLORA* AND *CASUARINA EQUISETIFOLIA* PROVENANCES IN SOILS LOW IN AVAILABLE PHOSPHORUS.

Acacia tortilis, *Prosopis juliflora* and *Casuarina equisetifolia* provenances were screened to determine their potential for adaptability under P limiting conditions as a strategy to exploit genotypic differences in terms of utilization and uptake efficiencies. The experiment was conducted in the greenhouse at the Kenya Forestry Research Institute using soils taken from the field which are critically low in available P. The experimental treatments comprised of P application at 0 and 60 Kg P_2O_5/ha for 11 provenances of *Acacia*, 6 *Prosopis* and 4 *Casuarina* spp. Trait for adaptability to P deficiency was determined by measuring the growth performance, P uptake and utilization efficiencies at zero and moderate application of P. The results indicated considerable differences in the growth performance and phosphorus use efficiency (PUE). *Acacia* provenances showed the highest PUE compared with *Prosopis* and *Casuarina* spp although this was not reflected in the total dry matter yield. However, it was observed that P application resulted in an increase in shoot dry matter, height, root collar diameter and root dry matter in the case of *Casuarina*. Similarly, the highest total P uptake was obtained in *Casuarina* and *Prosopis* spp. The results further indicated that P application probably contributed to the reduction in root dry matter and root:shoot ratios of *Acacia* and *Prosopis* but not *Casuarina* spp.

1. INTRODUCTION

Kenya is an agricultural country where 90% of the population which live in rural areas depend directly on small-scale agriculture for their livelihood. The sector is a major contributor to the country's GDP and an important source of formal and informal employment. However, farmers have reported steady decline in soil productivity over the last twenty years owing to continuous decrease in soil fertility, coupled with low nutrient inputs in manure and limited use of fertilizers.

Predominant soils are mainly low activity clays such as Acrisols, Cambisols, ferralsols and Luvisols [1]. These soils are low in available soil phosphorus, due to fixation of P into insoluble iron, aluminium and manganese hydroxy phosphates. This problem limits their ability to sustain agricultural production without supplementation with inorganic P fertilizers. However, owing to the inability of small scale farmers to purchase fertilizer inputs, agroforestry technologies involving use of woody perennials in cropping and pasture land use systems offer potential solutions as low input cropping strategy.

The main objective of this study was to identify Multi-Purpose Tree germplasm and provenances/genotypes which are adapted to phosphorus deficiency in the tropics. The following criteria were important in the choice of species for investigation: proven ability to grow in arid lands, existence in a wide ecological range, N_2-fixation ability, possession of adequate sizes of population and significant genetic variation within the species and between the provenances. *Acacia* and *Prosopis* spp provide an excellent opportunity taking into consideration the above criteria. A third choice was *Casuarina* spp which in recent times has been introduced in a wider ecological range in the tropics. More specifically, this study focused on the performance of three important species for arid and semi arid; *A. tortilis, P. juliflora* and *C. equisetifolia* at zero and moderate rates of P application. The characteristics and importance of these species have been underscored by many workers [2], [4], [5], [6], [7], [8], [9], [10].

2. MATERIALS AND METHODS

2.1. The greenhouse conditions

The pot experiment was conducted in the greenhouse at the Kenya Forestry Research Institute using soils taken from semi arid area at Machakos, Kenya which are classified as Ferralsols and Chromic Luvisols (Table I).

Acacia and *Prosopis* tree seeds were obtained from Oxford Forestry Institute in the U.K., while *Casuarina equisetifolia* seeds were provided by the Center Technique Forester Tropical (CTFT) in France. The *Acacia* and *Prosopis* seedlings were inoculated with a multistrain *Rhizobium* inoculant prepared by the Microbiological Research Centre (MIRCEN), Nairobi while *Casuarina* seedlings were inoculated with *Frankia* strain which was provided with the seeds from Center Technique Forestier Tropical (CTFC), France. Soil chemical analyses were determined prior to planting only for purposes of soil characterization. The soils were thoroughly mixed before filling the pots. A representative soil sample was then taken from each pot, mixed again, air-dried and sieved to pass through a 2mm screen. The seeds were germinated in trays and later pricked out and planted in the pots for the greenhouse.

TABLE I. CHARACTERIZATION OF SOIL FROM KATUMANI SITE USED IN GREENHOUSE EXPERIMENT

Parameter	Quantity
pH	5.6 ±0.1
Total N (%)	0.2 ±0.01
Organic C	1.3 ±0.5
Available P (ppm)	7.4 ±2.0
Exchangeable K (ppm)	12.2 ±1.2
Exchangeable Ca (ppm)	13.4 ±1.2
Exchangeable Na (ppm)	2.9 ±0.5
Exchangeable Mg (ppm)	3.8 ±1.5

2.2. Experimental design and sampling

The greenhouse experiment was laid out in a Randomized Complete Block Design (RCBD). The treatments comprised of P application at 0 and 60 Kg P_2O_5 /ha (equivalent to 0.6 g P_2O_5/hole at a plant population of 10,000/ha), 11 provenances of *Acacia*, 6 *Prosopis* and 4 *Casuarina* spp. The experiment was replicated three times. Standard pots measuring 20 cm in height by 20 cm top diameter and 10 cm bottom diameter were used. The average volume of soil per pot was 1.8 litres. Temperature, relative humidity and ventilation in the greenhouse were maintained to simulate the ambient temperature and humidity of the surrounding environment. The average day temperature was approximately 27°C while the relative humidity fluctuated between 70-80%. Watering of the seedlings in pots was regulated as the demand rose with the growth of trees.

The plant parameters measured included shoot and root dry matter yield, height, root collar diameter, root:shoot ratios, total P uptake and P use efficiency (PUE). Three randomly selected pots in each treatment per sub-plot (representing 50% of the total plant population) were used for the assessments. Total P concentration in the plant sample was determined by taking samples from the entire plant and mixing them together. The samples were then dried in a ventilated oven at 80°C for 24 hours and then ground with a Wiley mill. In the case of total P uptake, the samples were analysed calorimetrically using the Venado-molybdate method [11].

Dry matter yield was determined 12 months from planting time by destructive sampling followed by drying in a ventilated oven at 80°C for 24 hours. Total height was measured to the nearest centimeter while root collar diameter was recorded in millimeter.

2.3. Statistical analysis of data

With the exception of total P uptake and PUE, all the experimental data from the greenhouse experiment have been analysed on a species by species basis since more than one tree species was studied. This made it necessary for each species to be tested separately for variables such as growth parameters which cannot be compared. For the analysis of variance, experimental data were analysed as Randomized Complete Block Design (RCBD) for the traits which were tested to enable comparisons between the species and the provenances.

3. RESULTS AND DISCUSSION

The response to P by the different species and provenances are summarized in Table II and are further illustrated in Fig. 1. Generally, the application of phosphorus at medium level resulted in increased growth with regards to shoot dry matter, height and root collar diameter (Table II and Fig. 1). Both *Acacia* and *Prosopis* species showed reduced root dry matter production with application of P although in the case of *Casuarina* provenances a significant increase in root dry matter was observed as demonstrated by the results (Table II).

The results further showed that the application of P resulted in increased P uptake (Table II). *Acacia* provenances showed the highest PUE (Table II) compared with Prosopis and *Casuarina spp* although this trait was not reflected in the total dry matter production. *Acacia* provenances G8, G6, G7 and G5 (Table II), in this order were outstanding. This observation suggests that these provenances/genotypes can be grown in soils low in available P with minimum input of P. The high P uptake obtained in **Casuarina** appears to be positively correlated with root dry matter production following P application at moderate level. This probably indicates that high P absorbing genotypes are characterized by a higher root biomass. Available information from empirical and simulated data have shown that P uptake is related to changes in root growth, [12] and that differences among cultivars particularly at low P can be attributed to the degree of root growth [13] and [14].

TABLE II. EFFECTS OF P APPLICATION ON THE ROOT AND ABOVE GROUND (SHOOT) DRY MATTER, ROOT COLLAR DIAMETER, AND FOLIAR P CONCENTRATION OF *ACACIA TORTILIS*, *PROSOPIS JULIFLORA* AND *CASUARINA EQUISETIFOLIA* PROVENANCES AT 12 MONTHS AFTER PLANTING

Code Species	Provenance	Source	Root dry matter (g/plant)		Shoot dry matter (g/plant)		Foliar P conc. (%)		Root collar diameter (mm)		Height (cm)		Root:Shoot ratio	
			-P	+P	-P	+P	-P	+P	-P	+P	-P	+P	-P	+P
G1 *Acacia tortilis*	*spirocarpa*	Yemen	18.7	15.4	43.8	50.3	0.19	0.21	18.4	20.7	40.2	50.1	0.42	0.30
G2 *Aacacia tortilis*	*spirocarpa*	G.Sudan	21.0	17.5	36.4	48.4	0.18	0.24	18.5	18.3	43.4	48.3	0.58	0.35
G3 *Acacia tortilis*	*spirocarpa*	N.K.Sudan	13.2	15.5	33.3	50.6	0.16	0.24	19.2	22.6	63.5	65.2	0.39	0.30
G4 *Acacia tortilis*	*spirocarpa*	Israel	15.7	14.2	40.5	52.0	0.20	0.21	20.1	19.0	57.3	55.5	0.37	0.27
G5 *Acacia tortilis*	*spirocarpa*	Sudan	17.8	17.3	37.0	38.2	0.20	0.20	19.8	18.3	50.0	56.2	0.46	0.45
G6 *Acacia tortilis*	*tortilis*	India	20.2	18.0	48.1	60.1	0.17	0.19	18.0	23.4	62.3	78.1	0.42	0.30
G7 *Acacia tortilis*	*raddian*	Somalia	22.0	15.3	47.2	50.3	0.19	0.19	18.1	19.2	45.2	57.1	0.81	0.50
G8 *Acacia tortilis*	*raddiana*	Niger	16.0	18.4	40.1	47.4	0.18	0.18	22.1	22.4	60.9	58.0	0.40	0.38
G9 *Acacia tortilis*	*raddiana*	Rao Senegal	25.1	20.9	47.2	63.2	0.17	0.22	22.4	21.9	74.8	60.9	0.53	0.32
G10 *Acacia tortilis*	*heteracantta*	Zimbabwe	23.8	18.1	58.5	70.5	0.17	0.22	21.2	23.0	75.9	74.2	0.40	0.26
G11 *Acacia tortilis*	*heteracantha*	Zimbabwe	15.9	12.0	44.7	61.0	0.19	0.23	17.0	20.1	61.0	73.5	0.36	0.20
Mean			20.6	16.6	46.1	55.0	0.18	0.21	19.7	20.8	59.0	63.2	0.47	0.33
G12 *Prosopis juliflora*		Costarica	21.9	19.8	48.2	66.5	0.29	0.28	19.5	21.3	72.2	84.3	0.44	0.30
G13 *Prosopis juliflora*		Panama	25.8	23.2	53.8	80.8	0.26	0.25	20.0	22.8	68.7	77.6	0.47	0.30
G14 *Prosopis juliflora*		Columbia	19.7	18.9	55.6	75.0	0.22	0.30	17.8	22.0	69.8	80.3	0.35	0.25
G15 *Prosopis juliflora*		Honduras	20.5	22.0	60.0	71.8	0.24	0.25	17.6	20.1	66.9	77.6	0.34	0.31
G16 *Prosopis juliflora*		Kenya	23.7	20.6	58.5	69.8	0.25	0.29	18.8	20.6	73.2	81.4	0.40	0.30
G17 *Prosopis juliflora*		Peru	23.6	19.1	60.8	70.7	0.28	0.31	19.3	19.0	75.0	86.3	0.39	0.27
Mean			22.5	20.6	56.2	72.4	0.26	0.28	18.8	21.0	71.0	81.3	0.40	0.29
G18 *Casuarina equisetifolia*		Senegal Kayar	25.2	35.4	75.5	141.2	0.25	0.27	25.0	35.7	80.3	105.2	0.33	0.25
G19 *Casuarina equisetifolia*		Kenya-R.Island	30.2	33.7	68.7	128.0	0.28	0.29	27.0	38.2	85.1	110.7	0.44	0.26
G20 *Casuarina equisetifolia*		Senegal Dakar	27.8	40.0	72.9	135.3	0.24	0.30	24.4	32.1	78.0	104.5	0.38	0.29
G21 *Casuarina equisetifolia*		Australia	28.5	34.7	74.0	134.9	0.25	0.27	25.3	33.8	82.0	115.2	0.38	0.24
Mean			28.0	36.0	72.8	134.9	0.26	0.28	25.4	35.0	81.4	109.0	0.38	0.26
LSD P<O.05														
i)	For differences between species		11.2		14.1		0.10		2.1		19.9		0.2	
ii)	For difference between treatments/species		10.7		5.5		0.05		1.8		13.0		0.1	
iii)	For differences between treatments for the same species/provenances		5.0		10.1		0.06		2.7		5.9		0.1	

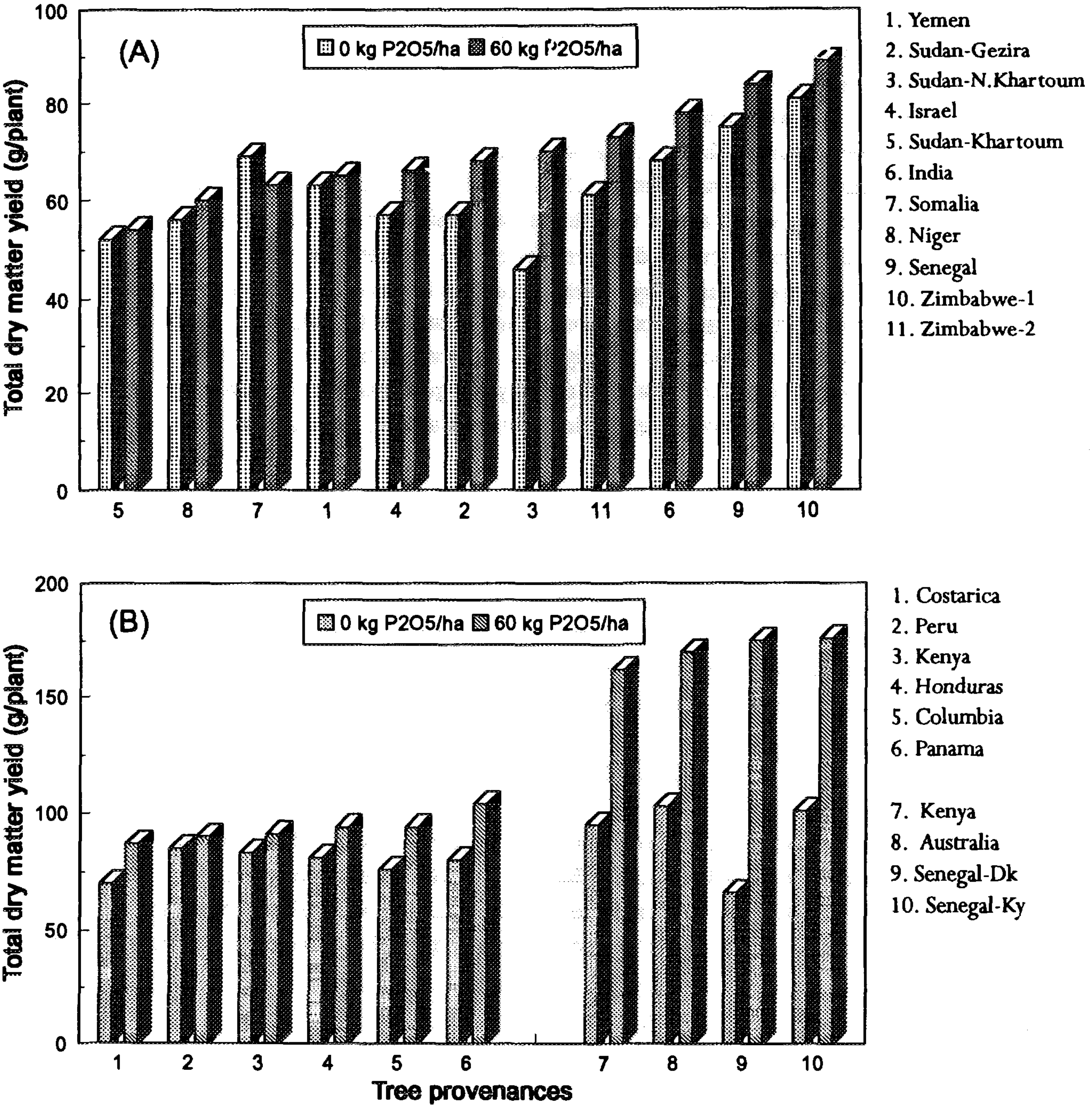

FIG. 1. Genotypic differences in total dry matter production of (A) Acacia provenances (1-11), and (B) Prosopis provenances (1-6), and Casuarina provenances (7-10).

The highest rate of response for shoot dry matter and height growth was obtained in the *Casuarina* provenances which was estimated to be 90% and 34% higher than treatments where P was not applied, respectively. In contrast with the above ground growth performance parameters, the results showed that *Acacia* and *Prosopis* species/provenances which did not receive P application produced higher root dry matter production which resulted in a low root/shoot ratio (Table II).

From the results, it is noted that P application conferred beneficial effects on the growth performance with the exception of root dry matter production for *Acacia* and *Prosopis* spp which appeared depressed following P application at moderate rate. These results therefore suggest that *Acacia* and *Prosopis* are more efficient in P uptake as shown clearly by their ability for increased root growth under P stress conditions. Smith [15] stated that an increase in root/shoot ratio often accompanies P deficiency which agrees with the results obtained in this study (Table II).

However, the application of these results at the moment may be limited taking into consideration that they are confounded by several factors, for instance, the relative degrees and trends in growth performance in the greenhouse could have been greatly influenced by the conditions existing in the greenhouse which are usually very different from those observed in the field. Furthermore, detailed agronomic/silvicultural and physiological analysis are extremely necessary in order to optimize the performance of genotypic differences at low, moderate and high conditions.

4. CONCLUSIONS

Although these results provide valuable information, they however, need cautious interpretations if they are to be used for formulating recommendations for provenance/genotypes choice for field application. Perhaps, the most immediate and logical step forward would be to confirm these results under field conditions to validate and prove consistency.

ACKNOWLEDGEMENTS

This work was supported and conducted under the FAO/IAEA/SIDA Coordinated Research Programme on water and phosphorus use efficiency, for which we are very grateful. The authors would like to thank Dr. K. S. Kumarasinghe of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture for his support and valuable contribution throughout the period of this investigation.

REFERENCES

[1] FAO/UNESCO Soil map of the world, Revised volume (1988) UNESCO, Paris.

[2] OLNG'OTIE, D.A.S., Genetic distribution of *Acacia tortilis*, Thesis D.Phil (1992) University of Oxford.

[3] NAS Firewood crops: Shrubs and tree species for energy production, National Academy of Science, Washington D. C. (1980) 237.

[4] HARLEVY, G., ORSHAN, G., Ecological studies on *Acacia* species in the Negev and Sinai, I. Distribution of *Acacia raddiana*, *A. tortilis* and *A. gerrardii* spp. *negevensis* as related to environmental factors, *Israel Journal of Botany* 21 (1972) 197-208.

[5] MAYDELL, von H. J., Trees and shrubs of the Sahel: their characteristics and uses, *Schriftenreihe der* GTZ, 196 (1986).

[6] LEAKEY, R.R.B., WILSON, J., MANSON, P. A., Agroforestry and mycorrhizal research for semiarid lands of East Africa, Institute of Terrestrial Ecology, Annual Report, Overseas Development Administration, London, England (1987).

[7] NAS Tropical Legumes: Resources for the future, National Academy of Science, Washington D.C. (1979) 331.

[8] FELKER, P., Mesquite - an all purpose leguminous and land tree, Economic Botany 36 (1982).

[9] FELKER, P., BANDURSKI R. S., Uses and potential uses of leguminous trees for minimal energy input agriculture, Economic Botany, 33 (1979) 172-184.

[10] *Casuarinas*: Nitrogen fixing trees for Adverse Sites, Australian Academy of Sciences, (1984) 16-33.

[11] Methods of analysis, Association of Official Analytical Chemists, 11th Ed. Washington D.C. (1970).

[12] Soil nutrient bioavailability (BARBER, S.A., Ed) John Wiley and Sons, Inc. USA (1984)

[13] BARBER, S.A., MAC KAY A.D., Root growth and phosphorus and potassium uptake by two corn genotypes in the field, Fert. Res. 10 (1986) 217-230.

[14] ROMER, W., AGUSTIN, J., SCHILLING, G., The relationship between phosphate absorption and root length in nine wheat cultivars, Plant and Soil, 111 (1988) 199- 201.

[15] SMITH F. W., Mineral Nutrition of legumes, In Nitrogen fixation of Legumes (Vincent, J. M., Ed) Academic Press, New York (1982) 155-172.