FERTILIZATION OF TIMBER WITH SPECIAL REFERENCE TO NPK RESPONSES FROM EUCALYPTS FIRST PLANTINGS

(Met opsomming in Afrikaans)

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Abstract

It is only during recent years that timber growers in the Republic of South Africa have been showing an active interest in the fertilization of timber, although positive responses to phosphorus have been demonstrated in the past. The main objective of the present research programme is to determine and evaluate long term economic effects of fertilization under various soil and climatic conditions on first plantings, replants and coppice of eucalypts, first plantings and replants of pines and first plantings of poplars. The results to date show a highly significant response to fertilization of first plantings of eucalypts, pines and poplars — almost 150 per cent increase in tree growth above the unfertilized controls. It is, however, quite obvious that the optimum NPK rates and ratios are largely determined by soil type and nutrient status of the soil. It is further found that sidedressing, within a relatively short period after planting, has a beneficial effect on trees which were not fertilized at time of planting. In the case or replants (eucalypts and pines) and coppice (eucalypts), however, results so far cannot conclusively justify fertilization.

Introduction

Approximately $2\frac{1}{4}$ million acres are at present planted to timber — this area being only slightly more than one per cent of the total land mass. It is estimated that an additional 40 000 to 50 000 acres per annum will be planted during the next 10 years bringing the total area under timber close to 3 million acres which is considered by many authorities as more or less the upper limit of land suitable for timber production. The main timber types grown commercially are pines, wattle, eucalypts and poplars. Since 1960 there has been a general trend to convert wattle plantations to pines, eucalypts and certain other agricultural crops. In this regard 250 000 to 300 000 acres of wattle land have actually been converted during the past few years.

As with other agricultural crops, foresters all over the world are being made aware that fertilization should form an integral part of silvicultural practice. In fact, the use of fertilizers in forestry is already well established in many parts of the world (Swan 1965). From the vast amount of research all over the world, one cannot but conclude that fertilization is economically justified in the majority of cases. Swan (1965), in reviewing the scientific use of fertilizers in forestry, states that the potential gains from fertilization are more immediate and of greater magnitude than those achieved by most other forms of intensive silvicultural practices. It is, therefore, rather strange that this aspect has, until recently, been largely overlooked in the forestry industry in South Africa. Perhaps, as pointed out by Youngberry (1964), it can partly be ascribed to the fact that many foresters still have the mistaken idea that trees need only water and light to make satisfactory growth.

Although local research by Donald (1963) and Deetlefs & Dumont (1963) has shown that certain spp of **Pinus** respond to phosphatic fertilizers, they concede that on poorer quality sites, the use of compound fertilizers could well be a profitable undertaking. In the case of fast-growing short rotation spp such as **Eucalyptus grandis** and **Eucalyptus cloeziana**, the response to fertilizers could be even more favourable from a financial viewpoint than in the case of lower yielding long term pine species (Dicks, Jackson & Kirk, 1965). Research on the soil fertility requirements of eucalypts grown in various parts of the world has shown that elements such as calcium, potassium, nitrogen and magnesium may be equally or even more important than phosphorus (Wilhelmij, 1966).

Due to lack of information on the merits of fertilization under local conditions and rather limited conflicting results when compared with research carried out in other parts of the world, an extensive research programme was started in 1964 — the primary object being to determine growth responses of eucalypts, pines and poplars to nitrogen, phosphorus and potassium and, in some cases, to calcium. The present research programme covers 18 statistically planned replicated field trials.

Until the above trials have completed their full felling cycles, the results presented in this paper should be accepted with some reservation. At the completion of these trials, the results will, in addition to physical growth responses, be evaluated with regard to long term economic effects, taking into consideration possible effects of fertilization on timber quality. A recent publication by Dicks, Jackson and Kirk (1965) reported on the results of one of the trials. In the present paper, results of all the trials received to date will be discussed briefly.

Materials and Methods

The trials were put down in the major timber growing areas in an attempt to cover as many of the dominant prevailing soil types and climatic conditions as possible. All the trials are being conducted on a co-operative basis both with the South African and Transkeian Departments of Forestry and a number of large privately owned timber companies.

The treatments in the majority of trials are selected combinations of a 4^3 factorial, with either 2 or 3 replications. The selected combinations are those used in the San Cristobal design as described by Rojas (1962). In some of the more recent trials, additional NPK combinations have been added. The four levels of the three factors under consideration, namely nitrogen (N) applied as limestone ammonium nitrate (26 per cent N), phosphorus (P) applied as superphosphate (8.3 per cent P) and potassium (K) applied as potassium chloride (50 per cent K), are equally spaced. The actual levels include a zero level of each element with maximum levels varying about 75 lb N, 60 lb P and 60 lb K per acre.

Nursery seedlings were selected for uniformity of height and vigour and varied from 8 to 12 inches at time of planting of trials on first plantings and on replants. In other trials, the trees were already well established at the time of fertilizer application. The gross plot sizes vary from 6 to 8 x 9 trees and the nett (measured) plots 2 to 4 x 5 trees.

In the case of first plantings and replants, the phosphorus and potassium were applied to each planting site at time of planting and worked in lightly soon after application. The application of nitrogen was delayed for 4 to 5 weeks to allow the transplants to establish a root system and to prevent possible nitrogen 'burn' to young seedlings. Subsequent observations indicated that this was unnecessary and nitrogen can therefore also be applied at time of planting or soon thereafter. For trials laid down in established plantations of replants and coppice (minimum age at time of fertilization 1½ years), the fertilizers were concentrated close to the tree or original stump and lightly worked in where possible.

Height and DBH measurements are being recorded for all trials. some of the trials, however, trees have grown to the extent where accurate height measurements of individual trees are practically impossible, in which case only DBH measurements are being made.

Certain details of the various trials are presented in Table 1.

Results

Due to the nature of this report, detailed results from individual trials are not presented, but only a summary of the results to date. This report should therefore be considered as an endeavour to indicate certain trends being obtained with fetilization of timber under local conditions.

The three aspects of investigation, viz first plantings, replants and coppice for the respective species will be discussed separately.

TABLE 1 *Details of the current fertilizer research programme undertaken by Fisons (Pty) Limited*

Code No	Co-operator and locality	Timber spp	Duration of trial—planted to last measuring date
T1(E)	Louws Creek Timbers, Barberton, E. Transvaal	E grandis (1st planting)	December 1964—February 1967 (December 1964)*
T2(E)	Louws Creek Timbers, Barberton, E. Transvaal	E grandis (1st planting)	December 1964—February 1967 (November 1964, November 1965—N sidedress)
T14(E)	Twello Forestry Corporation, Barberton (Inloop)	E coleziana (1st planting)	December 1965—July 1967 (December 1965)
T15(E)	Transkei Dept. Agriculture & Forestry, Transkei, E. Cape	E grandis (1st planting)	June 1965—July 1967 (January 1966)
T8(P)	S.A. Forestry Corp., Pilgrimsrest (In-de-Diepte), E. Transvaal	P patula (1st planting)	November 1964—July 1967 (November 1965)
T16(P)	Transkei Dept. Agriculture & Forestry Transkei, E. Cape	P patula (1st planting)	June 1965—July 1967 (June 1966)
T18(P)	S.A. Pulp & Paper Industries, Bulwer, N. Natal	P patula (1st planting)	November 1957—not measured (November 1967)
T19(Pop)	Lidgetton Land Co., Lidgetton, Natal	Populus deltoides (1st planting)	August 1965—August 1967 (November 1966)
T4(E)	Hunt Leuchars & Hepburn, Louis Trichardt (Boschdrift), N. Transvaal	E grandis (replants)	March 1965—July 1967 (September 1966)
T7(E)	Hunt Leuchars & Hepburn, Louis Trichardt (Ibibene), N. Transvaal	E grandis (replants)	January 1960—July 1967 (February 1966)
T5(E)	Louws Creek Timbers, Barberton, E. Transvaal	E grandis (replants)	June 1965—July 1967 (December 1966)
T9(P)	S.A. Forest Investments, Graskop (Driekop), E. Transvaal	P patula (replants)	December 1957—July 1967 (November 1965)
T12(P)	Usutu Pulp, Swaziland	P patula (replants)	March 1965—April 1968 (March 1966)
T21(P)	Jessievale Sawmills, Warburton, E. Transvaal	P patula (replants)	January 1967—not measured (October 1967)
T3(E)	Hunt Leuchars & Hepburn, White River, E. Transvaal	E grandis (1st coppice)	1957—applied November 1965—April 1967 (November 1965)

*Figures in brackets denote dates on which fertilization took place.

TABLE 2 Timber growth responses (first pntings of eucallyptas, pines and poplars) to NPK fertilization

Locality	Timber	Time (fertilized to last measuring date) in months	Mean soil analysis results (Exp site)							Texture	Optimum fertilizer levels in lb/acre			Increase above unfertilized controls as percentage
			pH (KCl)	P ppm	K ppm	Ca ppm	Mg ppm	Conductivity in ohms	CEC me%		N	P	K	
Louws Creek	E grandis	38 (38) (i)	4.2	5	125	195	95	112	—	R Sa Cl	60	10–15	20–30	140 (22.1) (ii)
Transkei	E grandis	18 (25)	4.0	15	305	550	65	67	18.4	Sa Cl Lm	40–60	15–30	0–25	124 (12.4)
Inloop (Barberton)	E cloeziana	31 (31)	4.3	5	120	170	60	35	7.5	Br Sa Lm	45	15	20	144 (11.0)
In-de-Diepte (Pilgrimsrest)	P patula	20 (32)	4.0	5	150	160	55	24	16.7	Br Sa Cl Lm	30	20–25	20–25	73 (5.1)
Transkei	P patula	18 (25)	4.0	5	125	240	90	33	18.3	Sa Lm	0–10	30–40	40–50	40 (6.9)
Lidgetton	Populus deltoides	9 (24)	4.6	30	55	2 550	540	39	33.1	Sa Cl Lm	50–75	15–30	20–40	58 (8.9)

(i) Age of trees at last measuring date.
(ii) Denotes mean tree height in feet obtained from the optimum NPK combination in the particular trial
NOTE The differences between unfertilized and fertilized trees (optimum levels presented) are statistically significant at the 5% level.
The CV values for all the above trials are lower than 20%.

First plantings — eucalypts, pines and poplars

A summary of the results obtained to date are presented in Table 2.

The dramatic increase in tree growth due to fertilization is clearly illustrated. In the case of eucalypts and poplars, nitrogen would appear to be the most important fertilizer component especially in the presence of phosphorus—ie a marked NP interaction is evident. With regard to nitrogen, similar results have been reported by research workers in other timber growing countries (Jerven, 1968; O'Hara, 1968 and Waring, 1967).

In the case of pines, the levels of nitrogen required appear to be much lower than that for eucalypts and poplars although at this stage it is doubtful whether one can generalize, especially in the light of results by Jerven (1968) where he foremost contributes to improved growth. There are indications that locality (especially soil type and rainfall) influence the optimum nitrogen requirements at planting. However, there is the possibility that nitrogen may induce a greater response when applied as a sidedressing to older trees than applications at time of planting.

Phosphorus and potassium, although equally important especially with regard to favourable interactions with nitrogen, are however, required at relatively lower rates. Tree growth increases for eucalypts vary from 124 to 144 per cent over controls. Due perhaps to differences in age and locality, the responses by poplars to fertilization are not of the same magnitude. Reference to Table 2 indicates that the poplar trial has been established on a more fertile site which may also account for the smaller differences between fertilized and control plots. According to Bonneau (1968) however, poplars show good reaction to fertilization even in soils apparently well supplied with nutrients.

Fertilization has also brought about a highly significant response in the growth of pines, with phosphorus tending to play a more dominant role than in the case of eucalypts and poplars.

When comparing the apparent optimum NPK levels with soil analysis results, it is quite obvious that there is no clear consistency or correlation — apparently soil type plays an equally important role. Growth responses in relation to soil analysis results will, therefore, most probably have to be calibrated on a soil type or series basis. This approach has been applied successfully in the case of crops such as sugarcane and maize in various parts of the world (Dahl, 1968; Schaife, 1968). In fact, Van Goor (1968) states that the only way to study the effect of fertilization on timber is by using multivariate analysis, bringing in climate, soil type, water, fertility status and history.

There is only one trial where the effect of sidedressing with N, P and K on first plantings of eucalypts are being investigated (Louws Creek — T2). A marked response to N, P and K applied as sidedressings to unfertilized trees one year after planting was obtained but no significant response when applied to trees which had been fertilized with N, P and K at time of planting, although the difference is none the less positive. The response to sidedressing was, however, not as marked as with fertilizer applied at time of planting. This is clearly shown by the results in Table 3.

TABLE 3 Eucalypts first planting response to NPK sidedressing

Application at time of planting (lb/acre)			Sidedressed one year after planting (lb/acre)			Mean tree height (in inches)
N	P	K	N	P	K	
0	0	0	0	0	0	77
0	0	0	30	15	40	112
40	22	33	0	0	0	205
40	22	33	30	15	40	218

Replants — eucalypts and pines

In two trials on **Eucalyptus grandis** (Louis Trichardt — Boschdrift and Ibibene — T4 and T7), no significant response to fertilization has been obtained to date. In the trial at Boschdrift, the fertility status of the experimental site is, judging by the soil analysis, exceptionally high which may be ascribed to the preceeding crop of pines, which in turn could be a reason for the poor response. The trees in this trial were fertilized 18 months after planting and measured 10 months after fertilization. In the trial at Ibibene, where the replants followed eucalypts, the objective has been to try to improve a very poor growth of 6 year old replants (in appearance comparable to 18 month old first plantings without fertilizer). Measurements were made 18 months after fertilization (age of trees $7\frac{1}{2}$ years). The lack of response at this stage makes it doubtful whether any responses will show up in future. The third trial on replants of eucalypts (Louws Creek, T5) shows a definite trend, although not significant, in favour of fertilization at a rate of approximately 40 lb N + 15 lb P + 35 lb K per acre with a mean average difference of 8 feet over the unfertilized control. These trees were fertilized 11 months after planting and measured 20 months after fertilization.

In the one trial on **Pinus patula** at Grasskop (T9), no significant response to fertilization has been obtained to date. Fertilizer was applied when the trees were 8 years old.

Although the present results cannot conclusively justify fertilization of replants of both pines and eucalypts, it could be that, with the fertilization of young stands, much higher level of nitrogen may be required. This aspect is being included in further research work.

Coppice — eucalypts

A high degree of variation in height measurements within 'like treated' plots of the only trial on coppice (White River, T3) makes comparison between treatments difficult. The trend is, however, in favour of fertilization. The trees in this trial were coppiced and fertilized towards the end of 1965 and were measured 18 months after fertilization. A possible reason for the 'poor' response on coppice may be due to the method of fertilizer placement. In the trial just discussed, fertilizer was concentrated close to the original stump. Alternative methods are being investigated.

Discussion

Although the trials on first plantings have not completed fullfelling cycles, there is every reason to believe that the existing dramatic differences between unfertilized and fertilized trees will be maintained or even increased. This statement is further substantiated by overseas work where, for example, Heiberg **et al** (1964) as quoted by Swan (1965) recently reported that **Pinus resinosa** plantations in New York State, fertilized 23 years ago, are still making 45 per cent more height growth than the controls. Likewise MacArthur (1957) reported in 1957 that in the Grand'Mere (P.Q. Canada) plantation, the mean annual increase in plots measured 36 years previously was three times that of the control. Shibamoto (1957) quotes figures showing that fertilization increased volume per acre by 45 per cent in 26 year old **Cryptomeria japonica** plantations. According to Jansen **et al** (1964) as quoted by Swan (1965), correct fertilization is capable of increasing the growth of young trees from 3 to 15 times. They furthermore conclude that the duration of the effect of fertilization is at least ten years but probably considerably longer.

Two important questions awaiting answers at this stage are whether increases in tree growth due to fertilization in the existing trials will be economically justified and what will the effect of fertilization be on timber quality. A final answer can of course only be given when each trial has completed its cycle. Jackson (1967), however, has made a preliminary economic evaluation of the results of the one trial on **Eucalyptus grandis** at Louws Creek (T1). His conclusions are that, if the value of round saligna mining timber is taken as 5 cents per cubic foot (which is considered rather conservative), the increased growth at this early stage has already paid for the fertilizer, the cost of application and the interest in these costs for a period of seven years at 8 per cent compound interest. Furthermore, it is probable that the best treatment plots will be ready for clear felling at the age of 6 years, whereas it is unlikely that the control plots will be ready before the age of 8 years or more. When the crop value is divided by overheads, insurances, fire protection, planting and tending costs plus interest for 6 years, instead of 8 years, the favourable financial implications of fertilizer appear to be very attractive.

With regard to the effect of fertilization on quality of timber, very little is known under local conditions. At present eucalypt timber is mainly used by the mining industry in the form of props or mats. This is in general a very 'unsophisticated' use of timber and fertilization is unlikely to have any adverse effect on the properties required of a mining timber. However, this may not be the case where eucalypts are grown for saw logs. The same applies to pines where the general aim is the production of saw logs and pulpwood. Naturally, pulpwood growers would welcome any improvement in the fibre structure. Much research has been done overseas on this subject and although there are some contradictions, the greater majority of results indicate an improvement in fibre quality (Jackson, 1968). Whether these results are applicable to local conditions is, however, difficult to assess at this stage.

The future of fertilizing first plantings of eucalypts, pines and poplars and sidedressing of unfertilized first plantings within a relatively short period after planting, seems promising. The same does not apply to replants and coppice. Possible reasons for the poor responses have been presented under 'Results'. Looking at favourable overseas results as reported by workers such as Conway (1962), Edlin (1962), Curtis (1964), Jerven (1968) and Hagner (1966), the poor responses obtained in the majority of the local trails may be ascribed to the relatively low fertilizer rates of nitrogen in particular and possibly potassium and phosphorus as well. In addition, the application method with regard to placement may also play an important part. As mentioned earlier, these aspects will be further investigated. Until results from these future investigations prove otherwise, one must at this stage accept the fact that fertilization of replants and coppice will in most cases not be economically justified in South Africa.

Opsomming

BEMESTING VAN BOSBOUBOME MET SPESIALE VERWYSING NA NPK REAKSIES BY EERSTE AANPLANTINGS VAN EUCALYPTUS

Dit is slegs gedurende die afgelope paar jaar dat daar 'n aktiewe belangstelling begin ontstaan het in die bemesting van bosboubome in die Republiek van Suid-Afrika, alhoewel positiewe reaksies met fosfaatbemesting in die verlede gedemonstreer is. Verdere navorsing, veral met Eucalyptus spp, het egter tot gevolg gehad dat bemesting tans al tot 'n redelike mate as produksiepraktyk aanvaar word. Die primêre doel van dié ondersoek, wat nog nie afgehandel is nie, is om die langtermyn ekonomiese effek van bemesting onder 'n wye reeks van grond- en klimaatstoestande by eerste aanplantings, herplantings en uitloop ('coppice') van Eucalyptus, en eerste aanplantings en herplantings van Pinus en Populus vas te stel. Verskeie veldproewe is in die verband uitgelê. Die resultate tot op datum toon hoogs betekenisvolle reaksies met bemesting by eerste aanplantings van Eucalyptus, Pinus en Populus. Vermeerderings in boomgroei van bykans 150 persent bo die onbemeste kontroles is verkry. Wat die optimum NPK verhoudings en hoeveelhede aanbetref, is dit egter duidelik dat dit grootliks bepaal word deur grondtipe en inherente voedingsstatus van die grond. Verder is gevind dat kantbemesting, indien redelik gou na plant toegedien, voordelig is by bome wat nie bemes was met plant nie. In geval van herplantings (Eucalyptus en Pinus) en uitloop (Eucalyptus) egter, regverdig die resultate tot dusver nog die onomwonde die algemene gebruik van bemestingstowwe nie.

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References

BONNEAU, M., 1968. The effects of fertilization at different types of site on mineral soil. Colloquium of the International Potash Institute on Forest Fertilization, 22-26 Aug., Jyväskylä, Finland.

CONWAY, M. J., 1962. Aerial application of phosphate fertilizers to Radiate Pine forests in New Zealand. Emp. For. Rev. 41 (3) 109, 234-245.

CURTIS, F. H., 1964. Fertilizing slush pine from the air. For. Farmer 23 (9), 8.

DEETLEFS, P. P. DU T. & DUMONT, M., 1963. The early response of Pinus radiata to fertilizer treatment. Forestry in S.A., 3, 101.

DAHL, D., 1968. New soil test interpretations outlined at Illinois Conference. Agric. Chemicals, March 1968, 56-59.

DICKS, H. M., JACKSON, D.A. & KIRK, R.D., 1965. The fertilization of Eucalyptus grandis/saligna. Reprint S.A. For. J. 54.

DONALD, D.G.M., 1963. The effect of phosphate fertilization on Pinus caneriensis in the Cape Midlands. Forestry in S.A., 3, 85.

EDLIN, H. L., 1962. Manuring ninety-nine year old Scots Pine: successful results in Norway. Quart. J. For. 56 (4), 328-330.

HAGNER, S., 1966. Timber production by forest fertilization. Paper presented at Meeting of the Fert. Soc., London, November 24, 1966.

JACKSON, D. A., 1967. Is fertilization profitable? Paper presented at De Kaap Timber (Barberton) field day. April 14, 1967.

JACKSON, D. A., 1968. Personal communication. Manager, Louws Creek Timbers (Pty) Limited, Louws Creek.

JERVEN, O., 1968. Brief summary of the evolution of forest fertilization in Norway. Colloquium of the International Potash Institute on Forest Fertilization, August 22-26 Jyväskylä, Finland.

MACARTHUR, J. D., 1957. The effects of manure on a white and Norway spruce plantation at Grand'Mere, Quebec. Tech. Note Far. Br. Cam. 64, 15 pp.

O'HARA, P. J., 1968. Leader growth and foliar composition of Sitka spruce in relation to fertilizer application on blanket peat. Colloquium of the International Potash Institute on Forest Fertilization, 22-26 August, Jyväskylä, Finland.

ROJAS, B. A., 1962. The San Cristobal design for fertilizer experiments. Proc. 4th Congress I.S.S.C.T., Mauritius, 1962.

SCHAIFE, M. A., 1968. Maize fertilizer experiments in Western Tanzania. J. Agric. Sci. Camp. 70, 209-222.

SHIMBAMOTO, T., 1957. Fertilizing forest lands. Forest and Estate Mutual Foundation, Tokyo, 35 pp.

SWAN, H. S. D., 1965. Reviewing the scientific use of fertilizers in forestry. J. For. 63 (7), 501-508.

VAN GOOR, C. P., 1968. Criteria for the determination of fertilizer needs in forestry. Colloquium of the International Potash Institute on Forest Fertilization, 22-26 August, Jyväskylä, Finland.

WARING, H. D., 1967. The role of nitrogen in the maintenance of productivity in conifer plantations. F.A.O. World Symposium on man-made forests and their industrial importance. Canberra, 14-25 April, 1967.

WILHELMIJ, H., 1966. The use of fertilizers and cash crops in eucalypt cultivation. Paper presented at September Meeting of the Eucalypt Sub-Committee of the S.A. Timber Growers Association.

YOUNGBERG, S. T., 1964. Forest fertilization in the Far West. Farm Chemicals, 127 (6), 54-55; 58; 60; 103.