The Role of Lime in Commercial Ginger Production in Australia

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Abstract

Liming is a long-established agronomic practice in the Australian ginger industry. A series of solution culture, pot culture and field experiments were used to examine the validity of existing liming recommendations.

In flowing solution culture experiments, no direct pH effects on ginger growth were evident over the pH range of 5.5 to 8.5, and ginger was found to have a very low external calcium requirement. A subsequent pot experiment using eight virgin soils obtained from ginger farms showed that the pH optima for growth were broad, but that micronutrient deficiencies, particularly copper and zinc, occurred at high pH values. A series of field experiments conducted on eight ginger farms generally confirmed the results of the pot experiment except that the pH effects were much smaller.

The current recommendation that ginger soils should be limed to pH 6.5 (measured in 1:5 soil/water suspension) is totally rejected; the lime requirement for 90% of maximum yield, while small or zero for most soils studied should be determined individually for each soil used in commercial ginger production.

Introduction

Commercial production of ginger (*Zingiber officinale* Rosc.) is restricted to a small area of coastal Queensland located in the region 60 to 160 km north of Brisbane. The soils upon which ginger is grown are generally acidic to highly acidic and growers have been advised to lime their soils to pH 6.5 (measured in 1:5 soil/water suspension) with lime or dolomite about six weeks before planting (Whiley, 1974). A survey of the industry conducted in 1974 showed that all commercial producers of ginger were liming their soils (Longworth and Knight, 1974). The origin of the above recommendation is obscure, but it almost certainly arose from early experience on krasnozems in the Buderim area where the industry was first established. Despite the widespread use of lime throughout the industry, reliable information on the effects of lime on ginger production was not available when the present project commenced.

This paper briefly summarizes the major findings of the research program conducted at the University of Queensland to separate and evaluate the direct effects of liming (pH change, improved calcium supply) on growth of ginger from the indirect effects, particularly pH-dependent changes in micro-nutrient availability.

Methods

The direct effects of constant solution pH and constant solution calcium concentration on the growth of young ginger plants were determined in separate experiments using the flowing solution culture technique (Asher and Edwards, 1978). Ginger rhizome pieces weighing 10-15 g were germinated in peat-moss (pH experiment), or in a mist propagation chamber (calcium experiment), following successive pretreatments with water at 51°C for 10 minutes, benlate, and 1000 ppm ethrel (Islam et al., 1978) and transferred to the experimental solutions. The solution pH experiment included seven pH treatments, viz. 3.3, 4.0, 4.8, 5.5, 6.5, 7.5 and 8.5. These were automatically controlled to within ± 0.1 pH unit of the designated value throughout the experiment. The solution of calcium concentration was 250 μM. The calcium experiment utilized six solution calcium concentrations, viz. 0.5, 3, 10, 100 1000 and 3000 μM, and was conducted at pH 6.0 ± 0.1. In both experiments, the temperature of the nutrient solutions was maintained at 25 ± 1°C, and the concentrations of all other essential elements were maintained at adequate levels.

A pot experiment using virgin soils from eight ginger farms was conducted in the glasshouse to determine the effects of varying soil pH on top growth, early rhizome yield, development of symptoms, and micronutrient content of plant tops. The pH treatments were established on the basis of lime titration curves determined for each soil. Basal macronutrients (N, P, K, S), but no micronutrients were applied. DTPA-extractable micronutrients (Lindsay and Norvell, 1978) were determined on all soils at all pH values both at planting and at harvest.

Finally, field experiments were conducted on eight commerical ginger farms to measure effects of varying soil pH on ginger yields under actual farming conditions. The effects of a "blanket" micronutrient treatment (B, Mn, Zn, Cu Mo) on the shape of the response curves were studied also. Soil pH was varied by addition of either lime or aluminum sulphate. These experiments were conducted during the 1976/77 growing season using a continuous function design (Foz, 1973; Hundtoft and Wu, 1974). Each 40 m long bed was divided into forty 1 m subbplots which differed in pH by about 0.1 pH unit from the preceding subplot. The experiment was replicated four times at each site. Fresh weights of rhizomes were obtained on two occasions corresponding to the early (March) and late (June) harvests in the industry. Soil pH (1:2 soil/0.01M $CaCl_2$) was measured in samples collected from the subplots at crop emergence and immediately following harvest. Some pH values were measured also in 1:5 soil/water suspensions to facilitate comparisons with recommendations based on water pH values. A PDP-10 computer was used to find curves of best fit relating rhizome yield to soil pH. Where effects of the micronutrient treatment were not statistically significant, data for the plus and minus micronutrient treatments was combined and a single curve only fitted.

Results

Response to ginger to solution pH

Ginger was found to have a broad optimum pH range in solution culture with growth not significantly affected by pH over the range 5.5 to 8.5 Although growth of ginger was strongly inhibited at the lower solution pH values, this species was clearly more tolerant to low solution pH than other species grown in the flowing solution culture units at the same time, with the exception of cassava cv. Nina which was also highly tolerant (Edwards et al., 1977; Islam et al., 1980). Roots of ginger grown at pH 3.3 showed symptoms of direct hydrogen ion injury, while at pH 4.0 root growth appeared healthy. Chemical analysis of the ginger tops indicated that magnesium uptake was almost certainly growth-limiting at pH 3.3 and 4.0, but not at pH 5.5 (Islam et al., 1980). Thus, if a higher solution magnesium concentration had been used than the 10 μm employed in this experiment, an even broader optimum pH range for ginger may have been observed.

Response of ginger to solution calcium concentrations

The results showed that ginger requires only a very low external calcium concentration for healthy growth Fig. 2. Thus, a solution calcium concentration as low as 2μM appears sufficient to achieve 90% of maximum yield. Eleven other species grown simultaneously with ginger required higher solution calcium concentrations (9-2, 500 uM) to achieve the same yield level. All were much more seriously restricted in growth than ginger at the lowest solution calcium concentration (0.5 uM). The low solution calcium requirement of about 2 uM for ginger is comparable to that of the more efficient species studied by Loneragan et al. (1968).

Calcium deficiency symptoms were clearly evident in ginger plants grown at 0.5 uM calcium. The only pseudo-stems present in this treatment were those which were present prior to imposition of the treatment.

The use of single superphosphate (20% Ca, 10% S, 9.1%) in the ginger industry at recommended rates up to 1,000 kg/ha^{-1} (Whiley, 1974) suggests that the calcium supply is extremely unlikely to be growth-limiting in commercial fields.

Soil pH and ginger growth – pot experiment

The response curves obtained when dry matter yields of tops and of rhizomes were plotted as a function of soil pH were mostly described best by quadratic equations. Cubic equations best fitted the other response curves. The relationships for two of the soils are shown in Fig. 3. Generally, rhizome yields were less sensitive than top yields to changes in soil pH. The response curves on all soils were characterized by broad pH optima with maximum yields being obtained at soil pH values, measured in 0.01M $CaCl_2$ ranging from 4.6 (Nambour) to 5.6 (Yandina). The corresponding water pH values associated with maximum yield ranged from 5.0 to 6.2, on all soils were below the currently recommended pH of 6.5 (Whiley, 1974). The results show that the pH effect on growth is soil specific and that no single pH value would give maximum growth on all soils.

The yield reductions observed in most soils at the higher soil pH values were accompanied by the development of copper and zinc deficiency symptoms (cf. Asher and Lee, 1975) which increased in severity with increasing pH. Diagnosis was confirmed by chemical analyses of plant tops. Several of the virgin soils were of marginal zinc and copper status (Table 1) and the yield reductions at high pH associated with a decrease in the amounts of DTPA-extractable copper and zinc to values less than 0.2 and 1.0 μM/g^{-1}, respectively.

Soil pH and ginger rhizome yields – field experiments

At six out of eight sites, a rhizome yield equal to or greater than 90% of maximum was obtained without any application of lime Fig. 4. However, at Yandina, the rhizome yield at the highest pH studied (pH 7.6) was 15% higher than in the unamended soil, and at Maleny an increase in yield of up to 11% was obtained by liming in the absence of micronutrient additions. About 1 t/ha^{-1} lime was needed to achieve 90% of maximum yield at Maleny and about 3 t/ha^{-1} was needed at Yandina.

Application of aluminum sulphate strongly depressed yields at four sites (Yandina, Beerwah 1, Nambour, Eumundi) but had little effect on yield at the others. Slight depressions in yield were obtained with the higher lime rates at several sites, notably Eumundi, Imbil, Beerwah 1, Maleny and Beerwah 2. However, the yield depressions at high lime rates were much less overall than was expected on the basis of the results of the pot experiment. The higher micronutrient status of the ginger soils on which the field experiments were conducted than of the virgin soils used in the pot experiment at least partially explains this discrepancy.

Soil pH values associated with $\geq$ 90% of maximum yield (Table 2) differ by more than 2 pH units across the eight sites irrespective of whether they are measured in 0.01M $CaCl_2$ or in water. The soil pH associated with 90% of maximum yield was greater than the recommended value of 6.5 (measured in 1:5 soil/water suspension) at the Yandina site alone. At the other sites it varied from 0.5 to greater than 1.8 units below the recommended value.

These results clearly illustrate the difficulty created by generalizing from a narrow data base, in this case a few observations of somewhat obscure origin in a single soil type to all soils currently used for commercial ginger production. Nevertheless, our data indicate that liming all soils to the recommended pH of 6.5 only caused a slight yield depression at two sites, viz. Maleny and Beerwah 2. The more pronounced yield depressions observed in some soils occurred at higher pH values. It is concluded that no yield benefit is to be expected from lime application on any of the soils examined except those at Maleny and Yandina. Furthermore, all ginger soils should be examined for responses to lime with recommendations on the use of lime related to soil type.

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Table 1 DPTA – extractable zinc and copper contents of eight virgin soils from ginger farms in southeast Queensland

Site	Soil Classification		DTPA – extractable	
	Great Soil Group (Australian)	Soil Order (U.S. Taxonomy)	Zn	Cu
			ug/g^{-1}	
Buderim	Krasnozem	Oxisol	3.18	2.88
Nambour	Alluvial soil	Entisol	2.55	1.72
Imbil	Krasnozem	Oxisol	0.90	1.93
Yandina	Yellow podzolic	Alfisol	0.93	0.50
Eumundi	Humic gley	Ultisol	0.81	0.48
Beerwah	Red earth	Alfisol	0.57	0.40
Beerwah	Humus podzol	Spodosol	0.28	0.48
Woombye	Red earth	Alfisol	0.15	0.26

Table 2 Soil pH measured in 1:2 soil/0.01M $CaCl_2$ and in 1:5 soil/water suspensions associated with ≥ 90% of maximum fresh rhizome yield at early harvest on eight ginger farms.

Site	Great Soil Group	Lowest pH, for yield ≥ 90% of maximum, measured in:	
		0.01M $CaCl_2$	Water
Palmwoods	Red earth	4.3	4.8
Beerwah 2	Red earth	4.3	4.7
Imbil	Krasnozem	4.4	4.9
Maleny	Krasnozem	4.6	5.1
Nambour	Alluvial soil	5.0	5.4
Beerwah 1	Humus podzol	5.0	5.7
Eumundi	Humic gley	5.2	5.9
Yandina	Yellow podzolic	6.4	6.9

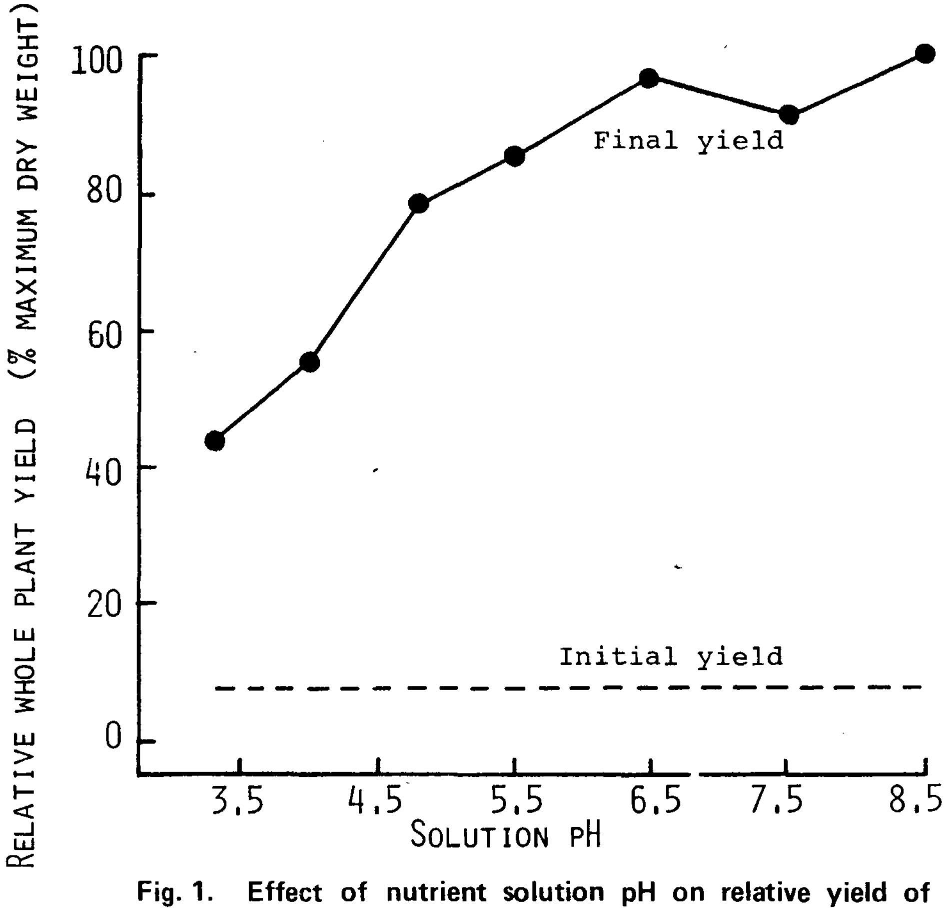

Fig. 1. Effect of nutrient solution pH on relative yield of Ginger after 42 days' growth.

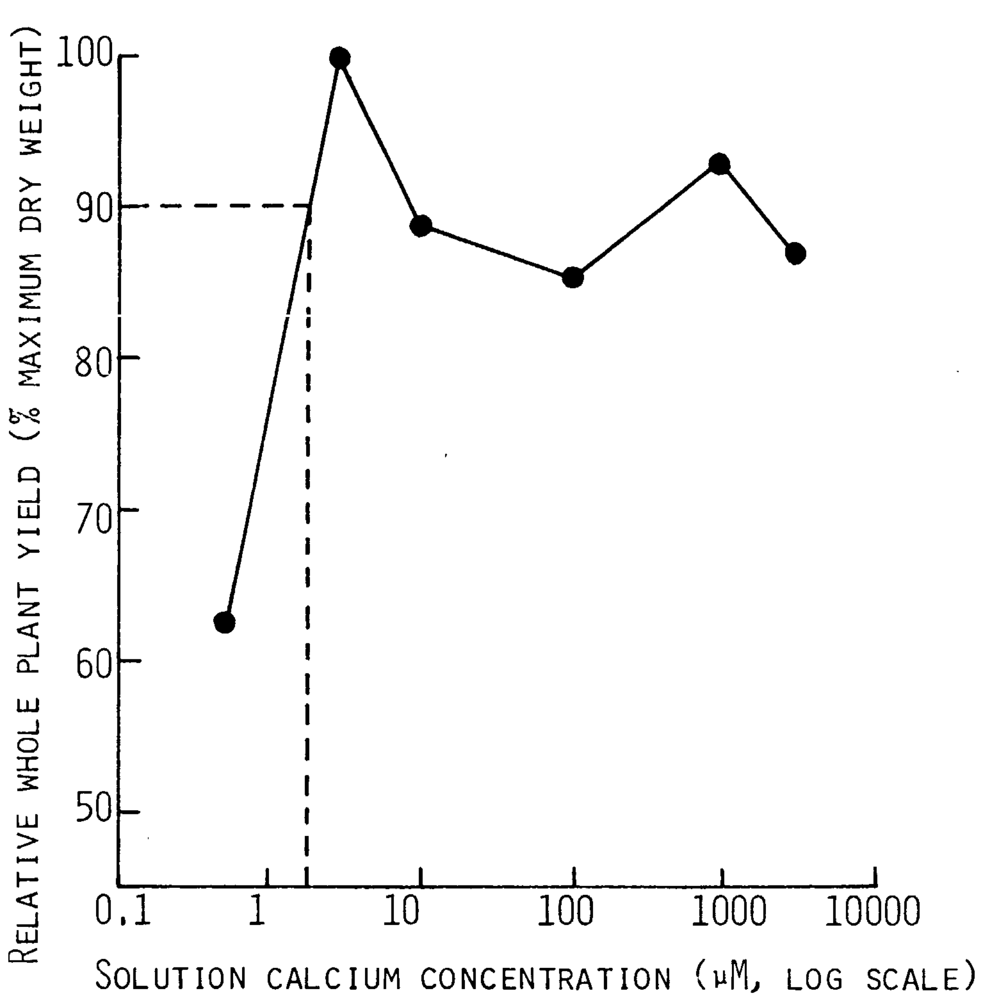

Fig. 2. **Effect of solution calcium concentration on relative yield of Ginger after 43 days' growth ($CaSO_4$ used as the calcium source).**

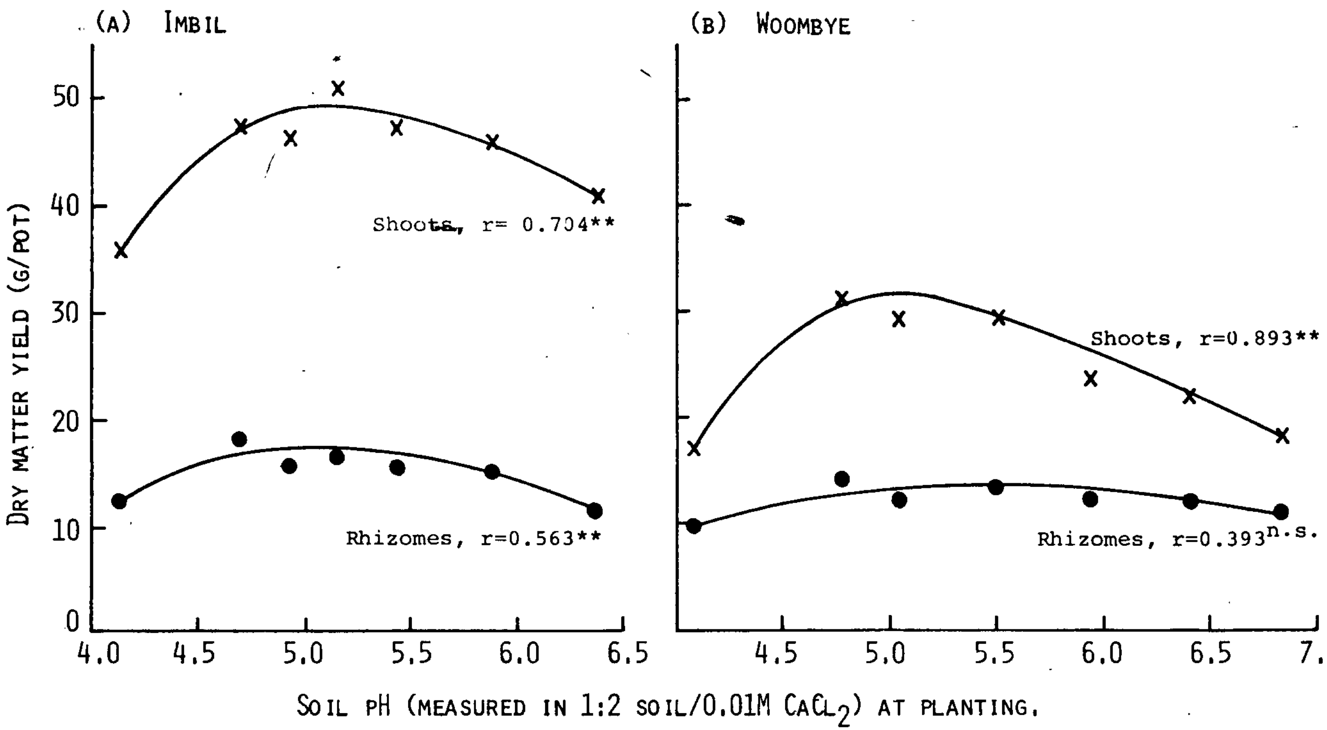

Fig. 3 Effect of soil pH on dry matter yield of Ginger shoots and Rhizomes from plants grown for 105 days in (a) Imbil soils and (b) Woombye soil, in a pot experiment ** Indicates significance at P = 0.01, $^{n.s.}$ indicates no significant effect.

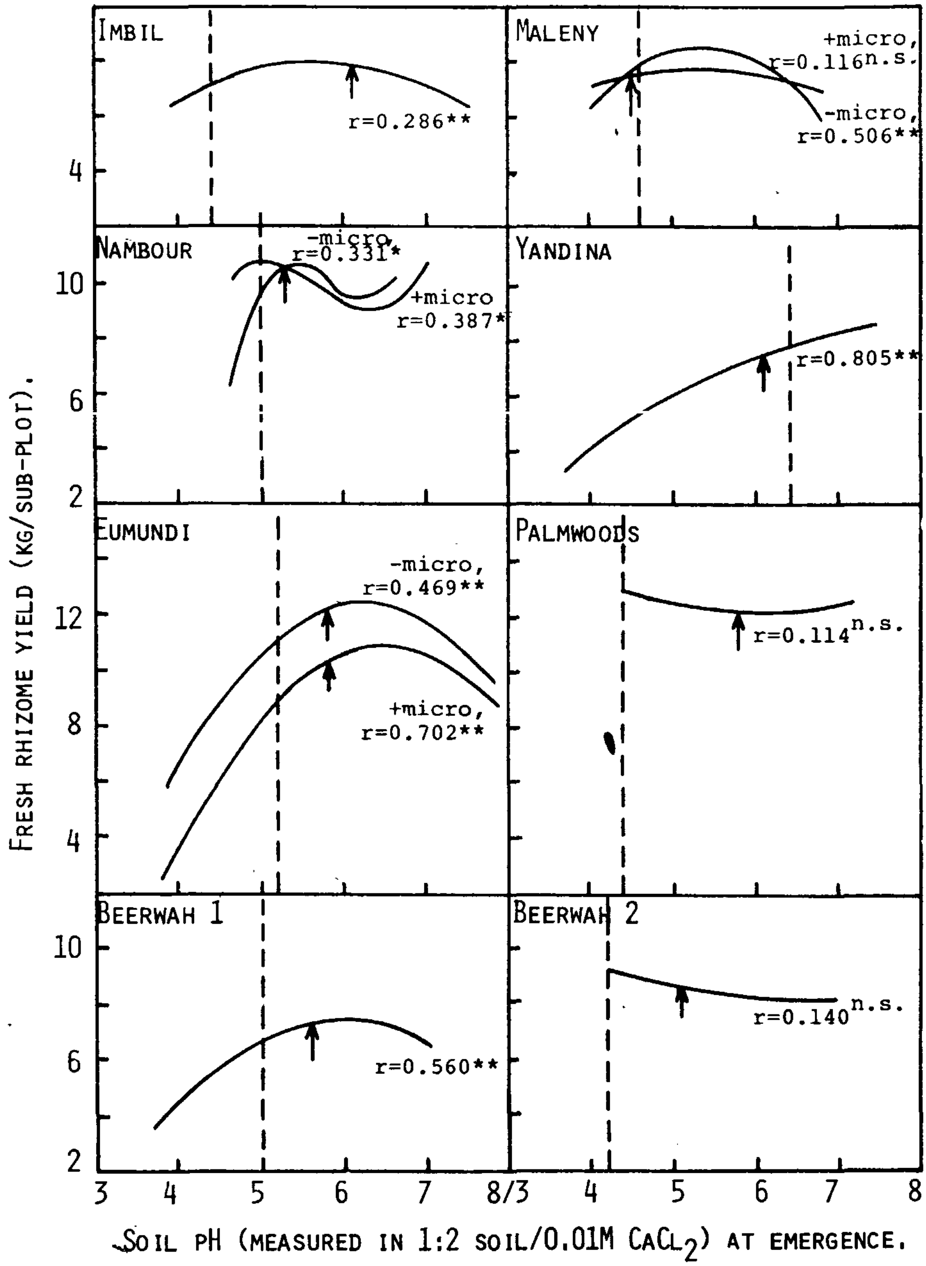

Fig. 4. Computer fitted curves relating soil pH at crop emergence to early harvest Rhizome yields. Arrows indicate yield obtained without soil amendment, vertical dotted lines indicate lowest soil pH that will give a yield of 90% of maximum, (1 kg/subplot = approx. 5.5 t/ha).