CHAPTER 6

RESPONSE OF POTATO GROWN IN A HOT TROPICAL LOWLAND TO PACLOBUTRAZOL. II: GROWTH ANALYSES

6.1 ABSTRACT

Two similar field trials were carried out during 2003 in a hot tropical region of eastern Ethiopia to investigate the effect of leaf and soil applied PBZ on the growth, dry matter production and partitioning in potato. A month after planting PBZ was applied as a foliar spray or soil drench at rates of 0, 2, 3, and 4 kg a. i. PBZ per ha. Plants were sampled directly after treatment application and subsequently two, four, six and eight weeks later. The data was analysed using standard growth analyses techniques. None of the growth parameters studied was affected by the method of PBZ application. PBZ decreased leaf area index, and crop growth rate, and increased specific leaf weight, tuber growth rate, net assimilation rate, and partitioning coefficient of potato. Although PBZ decreased crop growth rate, it improved tuber yield by partitioning more assimilates to the tubers. PBZ improved the productivity of potato under tropical conditions by improving assimilate allocation to the tubers.

Keywords: Assimilation, growth analysis; high temperature; potato; tropical lowlands;

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6.2 INTRODUCTION

Potato prefers cool weather and temperatures between 16 - 25 °C favour foliage growth, net photosynthesis, and tuberization (Levy, 1992). Although potato is a remarkably adaptable crop, its expansion has been restricted by high temperatures in some regions of the world (Levy, 1986). For instance, in Ethiopia about 35 % of the available agricultural land is situated in semi-arid regions of the country, where potato cultivation has not been practiced due to unfavourably high temperatures throughout the year. High temperatures in the tropics cause yield reduction and are considered the major constraints for potato production. Yield reduction is due partly to reduced assimilate production, delayed tuber initiation, and reduced assimilate partitioning to the tubers (Ewing, 1981; Menzel, 1980; Struik *et al.,* 1989; Vandam *et al.,* 1996)

The total dry matter yield of crops depends on the size of leaf canopy, the rate at which the leaf functions (efficiency), and the length of time the canopy persists (duration). A study of dry matter production and distribution to the various plant parts in the course of development is important for the evaluation of the growth rate, productivity and the yield level of potato.

Growth analysis has widely been used to analyse yield-influencing factors, explains observed differences in productivity and characterize plant development (Gardner *et al*., 1985). The commonly used growth analysis parameters are leaf area index, relative growth rate, net assimilation rate, and crop growth rate (Gardner *at al.,* 1985). Leaf area index is the ratio of leaf surface to the ground area occupied by the crop. Relative growth rate expresses dry matter weight increase in a time in relation to initial weight. Net assimilation rate is net gain of assimilates per unit leaf area and time. Gain in weight of community of plants on a unit of land in a unit of time reflects crop growth rate.

The production of assimilates by the leaves (source) and the extent to which it can be accumulated in the sink organs, determines crop yield (Hahn, 1977). Assimilate partitioning to the different sinks may be controlled by environmentally regulated hormonal balances (Almekinders & Struik, 1996). Yim *et al.* (1997) suggested the involvement of GA in regulating the pattern of assimilate partitioning in such a way that high GA level leads to a higher carbohydrate allocation to the shoots, where as low GA level resulted in more dry matter allocation to the roots.

PBZ is a triazole compound and interferes with *ent*-kaurene oxidase activity in the *ent*-kaurene oxidation path to block GA biosynthesis (Rademacher, 1997). It is proposed that PBZ treatment modifies the growth of potato under high temperature regimes by affecting growth parameters such as leaf area, specific leaf weight, net assimilation rate, and crop growth rate and tuber growth rate. This chapter presents analyses of the growth response of potato to paclobutrazol in a hot tropical region in eastern Ethiopia.

6.3 MATERIALS AND METHODS

6.3.1 Site description

Details of the site are presented in Chapter 5.

6.3.2 Plant culture

Cultural methods are described in Chapter 5.

6.3.3 Treatments

The treatments that were applied are presented in Chapter 5.

6.3.4 Data recorded

Directly after treatment application, and two, four, six, and eight weeks afterwards, three randomly selected plants were harvested from each plot. The samples were separated into leaves, stems, tubers, and roots and stolons. Green leaf area was measured with a portable CI-202 leaf area meter (CID Inc., Vancouver, Washington State, USA). Plant tissues were oven dried at 72 °C to a constant mass.

Growth analyses were conducted by computing the following standard formulae:

$LAI = [(L_{A2} + L_{A1})/2] * (1/G_A)$ (Gardner *et al.,* 1985)

$SLW = (L_{W2}/L_{A2} + L_{W1}/L_{A1})/2$ (Gardner *et al.,* 1985)

$CGR = 1/G_A * (W_2 - W_1) / (t_2 - t_1)$ (Gardner *et al.,* 1985)

$TGR = 1/G_A * (T_2 - T_1) / (t_2 - t_1)$ (Manrique, 1989)

$NAR = [(W_2 - W_1) / (t_2 - t_1)] * (\ln L_{A2} - \ln L_{A1}) / (L_{A2} - L_{A1})]$ (Gardner *et al.,* 1985)

$PC = TGR / CGR$ (Duncan *et al.,* 1978)

Where:

LAI is leaf area index; L_{A2} and L_{A1} are leaf area at time 2 (t_2) and time 1 (t_1), respectively; G_A ground area covered by the crop; SLW is specific leaf weight expressed in g cm^{-2}, L_{W2} and L_{W1} are leaf dry mass at time 2 (t_2) and time 1 (t_1), respectively; CGR is crop growth rate expressed in g m^{-2} day^{-1}, W_2 and W_1 are total crop dry mass (g) at t_2 and t_1; TGR is tuber growth rate expressed in g m^{-2} day^{-1}; T_2 and T_1 are tuber dry mass (g) at t_2 and t_1; NAR is net assimilation rate expressed in g m^{-2} day^{-1}; PC is partitioning coefficient.

6.3.5 Statistical analysis

The analyses of variance were carried out using MSTAT-C statistical software (MSTAT-C 1991). Combined analysis of variance showed no significant treatments by experiment interactions. Hence, for all of the parameters considered, the data of the two experiments were combined. Means were compared using the least significant differences (LSD) test at 5% probability level. Trends in different growth parameters were analysed by a linear regression, using Microsoft Excel 2000.

6.4 RESULTS

Leaf area index, specific leaf weight, relative growth rate, crop growth rate, tuber growth rate, net assimilation rate as well as partitioning coefficient were not affected by the method of PBZ application and consequently only the graphs of main effects of the treatment rates are presented.

PBZ significantly decreased the leaf area index compared to the control (Figure 6.1). The peak leaf area index for both treated (LAI = 3.9) and the control (LAI = 4.8) plants were attained 6 weeks after treatment application, about 60 days after planting. Irrespective of the concentration, PBZ treatment reduced leaf area indices by about 16, 21 and 19 % during the 2nd, 4th and 6th week after treatment application.

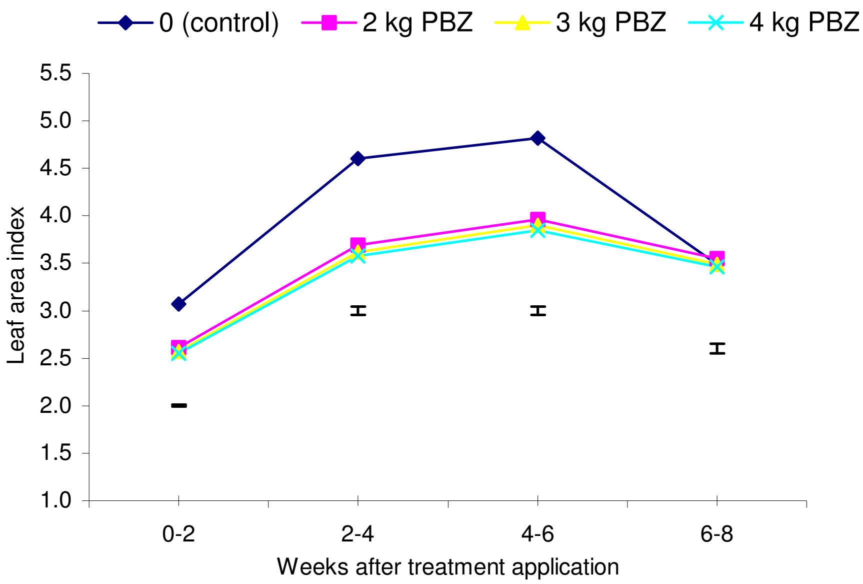

Figure 6.1. Leaf area index of potato as affected by rates of PBZ. The vertical bars represent least significant differences at P < 0.05

At all harvesting stages except for the first, PBZ increased the specific leaf weight (Figure 6.2). The highest specific leaf weight value for the control (4.1 mg cm^{-2}) as well as PBZ treated plants (4.3 mg cm^{-2}) were attained 4-6 weeks after treatment. The specific leaf weight increased sharply up to 6 weeks after treatment, and tended to decline slightly by week eight.

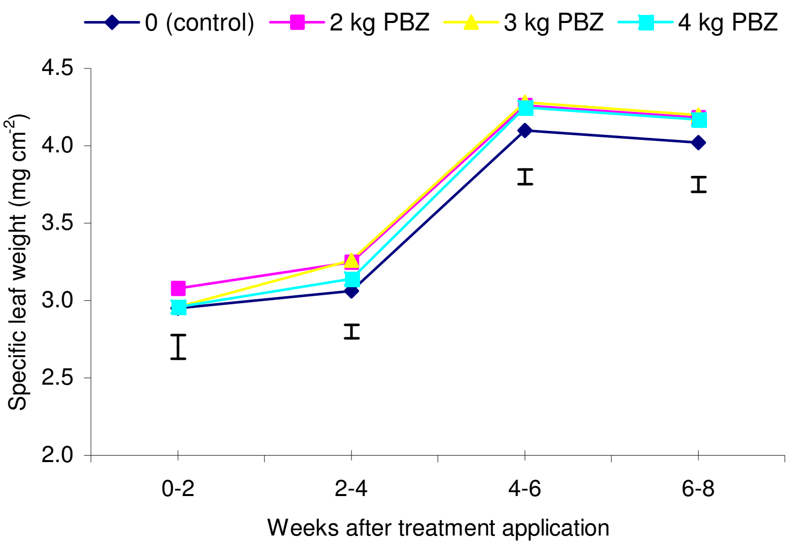

Figure 6.2 Specific leaf weight of potato as affected by rates of PBZ. The vertical bars represent least significant differences at P < 0.05

Crop growth rate of the control plants tended to be higher than that of the treated plants at comparable ontogenic stages (Figure 6.3). The maximum crop growth rates occurred in the interval 2-4 weeks after treatment, it slightly declined over the next two weeks, and sharply declined afterwards.

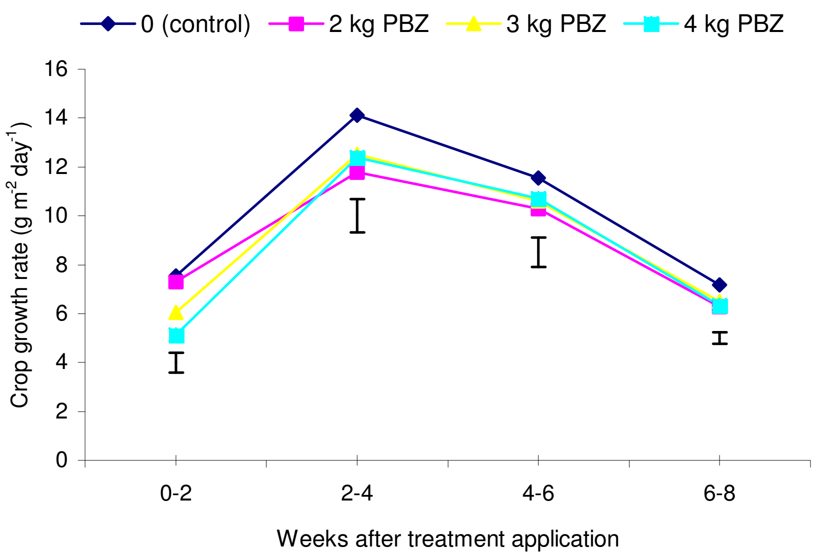

Figure 6.3 Effect of rates of PBZ on crop growth rate of potato. The vertical bars represent least significant differences at P < 0.05

PBZ enhanced the tuber growth rate (Figure 6.4). Up to 14 days after treatment, the control plants did not initiate tuber initials. Tuber growth rate increased to a peak of 5 g m^{-2} day^{-1} 4-6 weeks after treatment and showed a sharp decline afterwards.

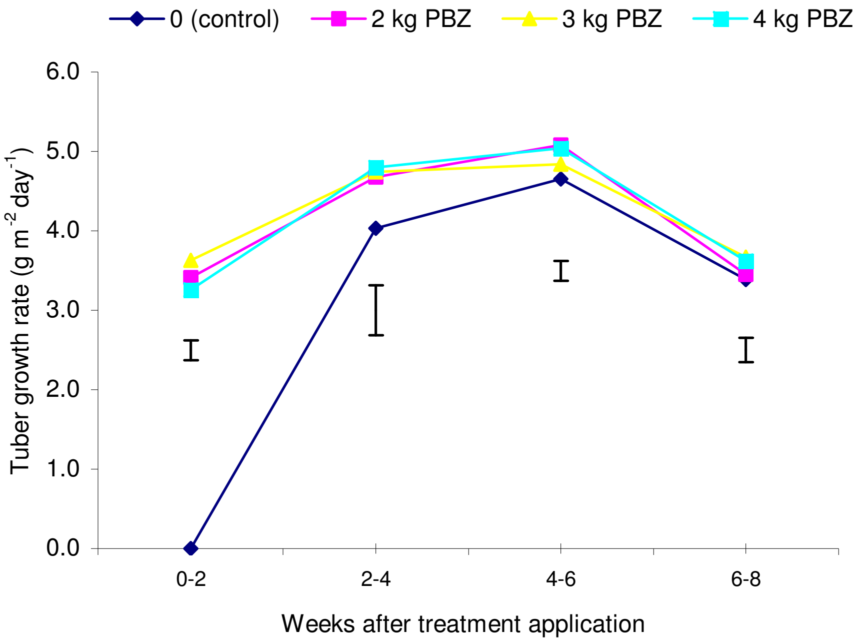

Figure 6.4 The effect of rates of PBZ on tuber growth rate of potato. The vertical bars represent least significant differences at P < 0.05

PBZ treatment slightly affected the net assimilation rate (Figure 6.5). During 0-2 weeks after treatment application, higher net assimilation rates were observed for plants which received 2 kg PBZ and for the control plants. During the 2nd and 3rd sampling periods net assimilation rate of 4 kg PBZ treated plants were slightly higher than the control. During the last sampling phase, no differences were observed among treatments with respect to net assimilation rate.

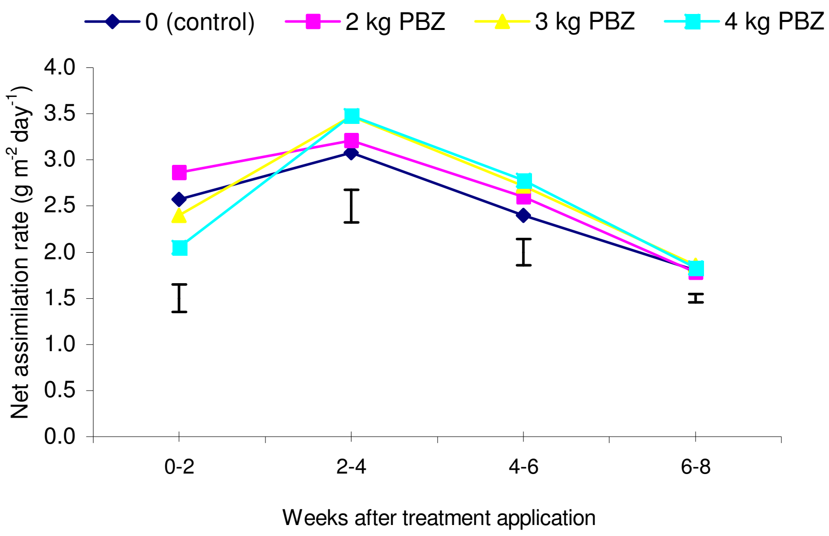

Figure 6.5 Net assimilation rate of potato as affected by rates of PBZ. The vertical bars represent least significant differences at P < 0.05

Dry matter allocation to the tubers was assessed by the partitioning coefficient (the ratio between tuber growth rate and crop growth rate). Although there was no significant difference at the third harvest, during the other harvesting periods PBZ increased the partitioning coefficient of the crop (Table 6.1).

Table 6.1 Partitioning coefficient of potato as influenced by different rates of PBZ

PBZ rate (kg a.i. ha^{-1})	PC			
	Week after treatment application			
	2	4	6	8
0 (control)	0.00c	0.29b	0.43a	0.47b
2	0.47b	0.40a	0.50a	0.54a
3	0.60a	0.38a	0.46a	0.56a
4	0.64a	0.38a	0.47a	0.56a
SEM	0.013	0.010	0.018	0.011

SEM: standard error of the mean.

Means of the same column sharing the same letters are not significantly different (P < 0.05).

6.5 DISCUSSION

The partitioning of carbon and nitrogen play a critical role in determining crop yield (Gifford & Evans, 1981). In most crops only part of the plant is utilized and hence the proportion of the total dry matter accumulated in the useful part of the plant is important, and will depend upon the sink strength of those organs. An understanding of the pattern of assimilate partitioning in potato is useful in determining potential yield, and to design strategies to increase tuber yield in the hot tropics and other areas where tuberization is poor. Triazoles are able to increase the partitioning of assimilates to tubers and roots and thereby increase yield (Fletcher *et al.,* 2000).

The mean leaf area index value of the control treatment (2-4 weeks after treatment) was approximately 4, which is the same order of LAI = 4.3 recorded 60 days after planting by Manrique (1989). PBZ reduced the leaf area index and this may be attributed to reduced GA activity in response to the treatment. It is postulated that reduced GA biosynthesis in response to PBZ treatment result in a reduction in cell proliferation, thus reducing leaf expansion. GA promotes cell division by stimulating cells in the G_1 phase to enter the S phase and by shortening the duration of S phase (Liu & Loy, 1976). Haughan *et al.* (1989) reported that the 2R configuration of PBZ retarded cell proliferation in celery. PBZ treatment decreased the length of wheat leaves by reducing cell length rather than cell number (Tonkinson *et al.,* 1995).

PBZ slightly increased leaf dry weight per unit area. Microscopic observations confirmed that treated plants had thicker leaves due to the induction of a thicker epicuticular wax layer, elongated and thicker epidermal cells, and palisade and spongy mesophyll tissues (Chapter 4). An increased leaf thickness in response to PBZ treatment has been confirmed in maize (Sopher *et al*., 1999), *Chrysanthemums* (Burrows *et al.,* 1992), and wheat (Gao *et al.,* 1987).

Net assimilation rates for the control treatment during the maximum tuber growth stage ranged from 2.5 to 3.5 g m^{-2} day^{-1}. This is lower than assimilation rates of 3 to 5 g m^{-2} day^{-1} reported for summer potato by Manrique (1989). The relatively lower net assimilation rate may be due to the poor adaptation of the cultivar used in the investigation to the prevailing high growing temperature.

The untreated plants exhibited a higher crop growth rate and a reduced tuber growth rate, while PBZ treated plants exhibited lower crop growth rates but a higher tuber growth rates. Higher leaf area is essential for higher biomass and tuber yield, however, in the current study it has been observed that the treated plants exhibited a higher tuber growth rate despite the reduced leaf area. This compensation could be due partly to enhanced net assimilation rate in response to the treatment. An increased tuber growth may also be attributed to an enhanced starch synthesis. From the microscopic investigation, it was clear that PBZ remarkably increased starch accumulation in the stem and root tissue of potato (Chapter 4). In the treated plants, numerous starch granules were observed in root and stem cortical cells as well as pith cells of the stem while cells in the control treatment were almost devoid of starch granules. It is evident from previous reports that high temperatures decrease tuber growth rate, reduce the partitioning of assimilates to the tubers and increase assimilation to other parts of the plant (Menzel, 1980; Struik *et al.,* 1989; Vandam *et al.,* 1996) which could be associated with increased GA activities

A reduction in crop growth rate and a concomitant increase in tuber growth rate increased the partitioning coefficient in PBZ treated plants. On the contrary, the untreated plants exhibited a lower partitioning coefficient due to excessive top growth and reduced tuber growth. Hence, it is reasonable to suggest that PBZ is effective in regulating top-tuber growth imbalance that occurred regularly in the tropics. Manrique (1989) reported a reduced partitioning coefficient in summer grown potato that was due to an excessive top growth and reduced tuber growth.

6.6 CONCLUSION

The growth analyses demonstrated that PBZ reduced leaf area index, and crop growth rate, slightly increased net assimilation rate and partitioning of assimilates to the tubers, enhanced early tuberization and increase subsequent tuber growth of potato grown in a hot tropical lowlands. Consequently, the productivity of the crop improved.