CHAPTER 11

GENERAL DISCUSSION

Problem areas identified and initiation of the experiments

Nature has designed a few food crops that are capable of nourishing mankind, and of these the potato is one (Talburt & Smith, 1967). Potato produces good quality protein and more calories per unit area per unit of time than any other major food crop (Swaminathan & Sawyer, 1983). In Ethiopia the great potential of the crop has not been adequately exploited as is clearly illustrated by the low national yield (10 ton ha^{-1}) and small area cropped to potatoes (36, 736 ha). A number of problems are responsible for the situation, of which two are addressed in this thesis.

1. Farmers in the eastern part of Ethiopia exports a variety of vegetable crops to Djibouti and Somalia of which potato is number one in volume of export and income earning. The highlands of the region are densely populated and the average land holding is estimated at about 0.25 ha per farmer. Since the majority of the population is greatly dependent on cereals as major source of food, most of the land is used for cereal production. Despite the potential of potato as a cash crop, production has been restricted due to shortage of land. Although there are huge virgin land resources in the lowlands of the same region, potato cultivation has not been practiced due to the fact that the prevailing high temperature inhibits tuberization. There is a clear need to develop appropriate technologies to introduce potato culture to the lowlands.

2. A lack of potato cultivars adapted to the different agro-ecological zones of the country is one of the problems accounting for low yields. To tackle this problem, the Potato Improvement Program of Alemaya University has been established with the major objective of developing adaptable and high yielding potato cultivars with good resistance to the biotic and abiotic stresses of the eastern part of the country. To achieve this the program has been introducing germplasm from the International Potato Centre (CIP) and testing it across locations. Most of the promising genotypes bloom profusely and some of them set berries under the growing conditions of the highlands of Eastern Ethiopia. The effect of flowering and berry set on growth, tuber yield and quality of potato is the second topic addressed in this thesis.

The need for plant growth manipulation

Lowland tropical regions are characterized by high temperatures that limit successful potato cultivation (Midmore, 1984). Unfavourably high temperatures promote foliage growth, decrease net photosynthesis, reduce assimilate partitioning to the tubers, and increase dark respiration (Gawronska *et al.*, 1992; Hammes & De Jager, 1990; Levy, 1992; Menzel, 1980; Thornton *et al.*, 1996). There is evidence that the inhibitory effects of high temperatures are mediated through the production of high levels of GA-like compounds known to inhibit tuber formation (Menzel, 1983). Previous studies showed that the hormonal balance controlling potato tuberization could be altered using GA biosynthesis inhibitors (Bodlaender & Algra, 1966; Menzel, 1980; Simko, 1994). PBZ is a triazole plant growth regulator known to inhibit GA biosynthesis and prevent abscisic acid (ABA) catabolism through its interference with *ent*-kaurene oxidase activity in the *ent*-kaurene oxidation pathway (Rademacher, 1997). It was hypothesized that by reducing GA biosynthesis, PBZ can improve potato productivity in the lowland tropics.

Response of potato to PBZ

The response of potato to foliar and soil applied PBZ was tested under non-inductive greenhouse conditions and in field trials in eastern Ethiopia as reported in Chapters 3, 4, 5, 6 and 7. PBZ increased chlorophyll *a* and *b* content and net rate of photosynthesis while reducing shoot growth, plant height, stomatal conductance, the rate of leaf transpiration, and tuber number per plant. It enhanced early tuber formation and delayed the onset of leaf senescence, and decreased the partitioning of assimilates to the leaves, stems, roots and stolons while increasing partitioning to the tubers. Growth analyses demonstrated that PBZ decreased leaf area index and crop growth rate while increasing specific leaf weight, tuber growth rate, net assimilation rate, and partitioning coefficient (harvesting index). PBZ treatment extended the dormancy period of the tubers. Although PBZ decreased crop growth rate, it increased tuber yield by about 58% and dry matter content of tubers by 7% over the control, probably due to the interplay of early tuber initiation, higher tuber growth rate, enhanced net photosynthesis and the diversion of more dry matter to the tubers. Balamani & Poovaiah (1985) and Simko (1994) also reported an increased tuber dry mass per plant in response to PBZ. PBZ increased tuber N, Ca and Fe concentrations while reducing P, K and Mg contents. For most of the parameters considered no significant differences were observed between methods of PBZ application. The investigation showed that PBZ is effective in suppressing excessive top growth and favouring assimilate partitioning to the tubers, thus improving tuber yield and quality. The PBZ-induced yield and quality improvement obtained in the lowlands of eastern Ethiopia may be an important step towards designing viable potato production programs for this region.

PBZ induced anatomical and morphological changes in potato (Chapter 4), which have not been clearly documented previously. The green colour of the leaves intensified because of increased chlorophyll *a* and *b* content in response to PBZ treatment. Increased leaf thickness is attributed to a thicker epicuticular wax layer, and elongated and thicker epidermal, palisade and spongy mesophyll cells. PBZ also increased leaf thickness in *Chrysanthemum* (Burrows *et al.,* 1992), maize (Sopher *et al.*, 1999), soybean (Hawkins *et al.,* 1985) and sugar beet (Dalziel & Lawrence, 1984). The increase in stem diameter was due to the formation of thicker cortex, well-developed vascular bundles, and a larger pith diameter. An increase in the thickness of the cortex and the induction of more secondary xylem vessels in response to PBZ treatment increased the root diameter. PBZ remarkably increased starch synthesis as clearly demonstrated by the deposition of starch granules in stem pith cells and cortical cells of the stem and root. PBZ treatment also increased root starch content in maize plants (Baluska *et al.,* 1993) and in the leaves, stems, crowns and roots of rice (Yim *et al.*, 1997). An understanding of the effect of PBZ on anatomical features and physiological processes can contribute greatly to our understanding of plant growth processes, and to the utilization of PBZ and similar compounds to manipulate growth.

Growth and productivity of potato as influenced by cultivar and reproductive growth

To investigate the effect of cultivar, and flower and fruit development on the growth, tuber yield and tuber quality, non-flowering, flowering and fruiting plants of four cultivars were evaluated in the sub-humid tropical highland of eastern Ethiopia (Chapter 8 and Chapter 9). Cultivars exhibited differences with respect to leaf stomatal conductance, rate of transpiration, photosynthetic efficiency, tuber yield, dry matter content, and nutrient composition. This variability may be useful for the selection of cultivars characterized by high rates of net photosynthesis, suitable for processing or table consumption, and cultivars with reduced rates of transpiration more adaptable to moisture limited areas.

The presence of berries increased leaf stomatal conductance and rate of leaf transpiration, which may limit the productivity of the crop under moisture deficit conditions. Fruit development reduced leaf area index, tuber growth rate, assimilate partitioning to the leaves, stems, and tubers, and promoted early plant maturity. Although berry development increased photosynthetic efficiency, net assimilation rate and crop growth rate, it decreased final tuber yield and dry matter content due to the diversion of assimilates to the developing berries. Flowering and berry set restricted vegetative growth and decreased the partitioning of assimilates to the tubers thereby reducing tuber yield and dry matter content. Bartholdi (1940) reported that sexual reproductive growth reduces vegetative and tuber growth. In an investigation on the effect of flowering and berry set in *Solanum demissum Lind.* ProundFoot (1965) observed that reproductive growth significantly reduced tuber yield. Flower removal increased tuber yield and increased dry matter contents (Jansky & Thompson, 1990, Tsegaw & Zelleke, 2002).

The need for chemicals to prevent flowering and berry set

The current study as well as a previous investigation conducted at the same experimental site using the same cultivars (Tsegaw & Zelleke, 2002) demonstrated that berry set restricted vegetative growth and decreased tuber yield and dry matter content. Hence, simple and economical means to control flowering and berry set in potato should be investigated. Accordingly, greenhouse and field experiments were conducted with a major objective of studying the effect of MCPA and PBZ on flowering, berry set and biomass production, yield and quality of potato (Chapter 10). Both MCPA and PBZ completely prevented flowering and berry set without negatively affecting yield and quality. PBZ treatment at early flower bud stage resulted in a higher tuber yield than application during the late flower bud stage. Wedgwood (1988) achieved best control of berry production in potato with a combination of MCPB and Bentazone applied at the full foliage to flowering stage. Application of MCPA at early flower bud stage reduced berry set, according to Veerman & Van Loon (1993). The study demonstrated that a single foliar spray of MCPA or PBZ at the early flower bud stage at a rate of 250g a.i. ha^{-1} was effective to inhibit flower formation and prevent berry set.

Aspects that need further investigation

In the course of study various aspects for future research opportunities have been identified of which the most important are outlined:

1. There are restrictions on the utilization of products from PBZ treated plants. For instance, a residue of 0.5 mg PBZ per kg fruit is the internationally acceptable standard for mango fruit (Srivastava & Ram, 1999). The residual levels of PBZ in potato should be established before the use of the chemical for commercial purposes can be considered.

2. It has been observed that PBZ application increased the dormancy of the tubers. The effect of PBZ on dormancy characteristics and performance of seed tubers from treated plants must be investigated.

3. PBZ enhanced the photosynthetic rate as well as starch deposition. The mechanisms how PBZ affects these processes are not well understood and it needs further study.

4. The response of potato to prohexadione-calsium, a new plant growth retardant with low toxicity and limited persistence (Owens and Stover, 1999), and similar new growth

regulators, ought to be investigated in order to ascertain whether more effective or potentially safer products than PBZ are available.

5. Flowering and berry set reduced the productivity of potato by reducing both tuber yield and dry matter content. The negative effect of reproductive growth on the productivity of potato must be considered in cultivar selection strategies. Chemical means of preventing flowering and berry set need to be evaluated at farm level.