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The influence of pre-planting treatments, organic and mineral fertilisers on potato production

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Abstract - Yield of potato crop is influenced by many pre-planting treatments such as : nitrogen irrigation, nitrogen fertilizers as well as cattle manure, gibberillic acid, sulfur and thiourea. In fact they improve protein expressions patterns, leading to an increase of potato yield by increasing number of tubers and tubers weight. Production history of tubers mothers anlight influence also significantly potato yield.

Key-words : Potato, yield, nitrogen, cattle manure, sulfur.

Introduction

Performance of potato crop is complex and is influenced by a large number of changeable factors including; disease, nutrition, leaf surface, environment, mother tubers and genetics. Environmental factors especially day length and temperature play a major role in tuber initiation. Although these factors are effective on tuber productivity, it was proved that organic and chmineral fertilisers influence by the growth regulatory materials or plant growth regulators (PGR) and especially changing the levels of "endogenous Gibberellins" (Bielek, 1974 , Barani *et al.*, 2013). There is concern over the sustainability and environmental impact of mineral fertilisers and crop protection inputs used in intensive arable crop production systems. However, replacing mineral with organic fertilisers (animal and green manures) and restricting the use of chemosynthetic crop protection may significantly reduce crop yields (Abou- Hussein et *al.*, 2003). The effects nitrogen of replacing mineral with composted cattle manure fertiliser input and omitting pesticide-based crop protection on potato tuber yield, leaf and tuber mineral nutrient content and leaf protein profiles were investigated in this study. The effect of some chemicals (Gibberillic acid, sulfur, thiourea) on potato performance were established in this review. The influence of pre-planting treatments on potato emergence, on number of tubers, on tuber weight, on yield were also studied as well as the effect of production history and light on potato production.

1. Chemicals

1.1 . Nitrogen

Nitrogen Fertilizer

Nitrogen is an important nutrient for the activity of plant organs (Sincik *et al.*, 2008). Nitrogen fertilizer can increase N uptake and subsequently its concentration in the leaves. An increased N content stimulates the photosynthetic capacity by the elevation of the content of stromal and thylakoid proteins in leaves (Abou hussein *et al.*, 2003). Previous studies have mentioned the positive effect of nitrogen supply in the form of in increased leaf expansion and stem branching capacity (Alam *et al.*, 2007). Thus, the shoot dry matter and subsequently the total crop yield can be increased by increasing the concentration of nitrogen fertilizer up to an optimal level. These results are in agreement with the previous reports (Sincik *et al.*, 2008).

Nitrogen Irrigation

Neither irrigation nor N treatments had an influence on the potato tuber yield. Potatoes did not emerge 100% due to the heavy rainfall right after planting. Reduction of both total and marketable yield was recorded in this year. Leaching rainfall in the early season and poor tuber set could be responsible for the lower yields compared to the yields in the other two years (Zvomuya *et al.*, 2003 ; Fransisco *et al.*, 2008). Nitrogen sources did not affect the average NO_3-N concentrations in the perched groundwater in any year. This may be due to a high dilution of nutrients in the water table. Pack *et al.*(2006) found also that no significant difference in NO_3-N concentration was found between treatments in water. Smajstrla *et al.* (2000) suggested that in sandy soils, leaching of urea-N can be an important part of total N loss from urea-based slow-release fertilizers, especially with the first precipitation events. The lower N leaching from urea might be the result of loss N through volatilization and denitrification. Waddel (2000), Waddel *et al.* (2000) and Wilson *et al.* (2003) suggested that urea-N could be lost by leaching of unhydrolyzed urea, volatilization and greater loss through leaching due to more rapid nitrification compared to ammonium N source.

1.2. Cattle Manure

The administration of organic manure to the soil may enhance the solubility of some nutrients such as zinc and phosphorus (Goffart *et al.*, 2008). On the other hand, the supply of animals manure can result in the improvement of soil characteristics (physical and biological). The increase of the above mentioned soil nutrients and other factors can encourage shoot growth and elevate the metabolism of photosynthesis (Abou-Hussein *et al.*, 2003) . In the same way, Kumar *et al.* (2007) have shown that the increased plant height, shoot number, leaves area, and total dry matter accumulation were obtained by the application of appropriate amount of farm yard manure. Abou-Hussein *et al.* (2003) have observed that the fresh weight of potato shoots, plant height, and tuber yield were increased significantly by the combined administration of cattle and chicken manure (Najm *et al.*, 2012). The increases of plant height and tuber yield with the integrated use of cattle manure and nitrogen fertilizer were due to their positive effects, as mentioned above. The current results are in-line with those of Alam *et al.* (2007) and Zelalem *et al.* (2009) which demonstrated that the maximum

amounts of plant height, shoot dry matter and tuber yield of potato were obtained by the combined administration of vermin compost and chemical fertilizer. So it can be concluded that the separate application of nitrogen fertilizer and cattle manure has a positive effect on plant height and in growth season but their combined use has more beneficial effect on the above-mentioned parameters. It has also concluded that the maximum amount of tuber yield was obtained by combined administration of cattle manure and nitrogen fertilizer at the concentrations of 20 tons ha^{-1} and 150 kg N ha^{-1}, respectively. So, the integrated use of cattle manure and nitrogen fertilizer could be a suitable solution for achieving optimum growth characteristics and subsequently increased tuber yield.
In the same vision, switching to organic fertiliser had a greater effect on yield and protein profiles than the omission of chemosynthetic crop protection (Sincik *et al.*, 2008). Leaf N and P composition were significant drivers of protein expression, particularly proteins involved in photosynthesis such as the large subunit of RuBisCO, RuBisCO activase and the photosystem I reaction centre, which were at higher abundances in potato leaves grown under mineral fertiliser regimes (Zelalem *et al.*, 2009). Proteins known to be induced in response to stress, such as dehydroascorbate reductase and Glutathione *S*-transferases, were also shown to be up-regulated under mineral fertilisation, possibly associated with higher Cd composition, whereas two proteins known to be involved in biotic stress (1,3-β-D-glucan glucanohydrolase; putative Kunitz-type tuber invertase inhibitor) were more abundant under compost fertilisation (Alam *et al.*, 2007). Results showed that switching from mineral to organic fertilisers led to reduced N availability, a significant change in leaf protein expression and lower tuber yield. In contrast, omission of chemosynthetic crop protection inputs had limited effects on protein expression and no significant effect on tuber yield (Goffart *et al.*, 2008). These studies provides information on the effects of changes in nutrient supply on protein expression patterns. It is a prerequisite for the development of functional molecular markers for a directed strategy to inform breeding programmes to improve potato nutrient use efficiency (Kumar *et al.*, 2007 ; Najm *et al.*, 2012).

1.3. Gibberellic Acid

Salimin *et al.* (2010) reported that gibberellic acid (GA) was effective in interrupting the dormancy of mini-tubers. However, the sprouts that developed in the GA-treated tubers were easily broken during handling and planting. Other sprouting inhibitors are also effective in interrupting dormancy or sprouting management (Beaver *et al.* 2003; Bajji *et al.* 2007; Teper-Bamnolker *et al.*, 2010), but the effects of treatments on seed potatoes have not been studied. Alexopoulos *et al.* (2008) used GA at a concentration of 1–50 mg/l and found that treatment duration appears to be more important than GA concentration. In their sprouting management studies, Pruski *et al.* (2006) discovered that treatment of seed potatoes with ethylene during storage resulted in larger numbers of sprouts and increased the number of tubers, but did not result in higher crop yield. Production and storage conditions (Van Ittersum 1993) as well as carbohydrate metabolism and plant hormones (Daniels-Lake and Prange, 2007) also influence dormancy.These constatations were in line with the results of Pruskin *et al.* (2006) : i.e.100 mM GA concentration increased the number of tubers but did not affect crop yield. Sprouting management strategies and methods are particularly needed in production conditions where storage lasts several months and the growing season is short (Veerman and Wustman, 2005; Daniels-Lake and Prange, 2007). Even though the metabolism of seed potatoes (dormancy, sprouting management) can be influenced (Struik and Wiersema, 1999), the effects of production history have to be predicted and managed. Tubers behaved as physiologically young seed potatoes regardless of haulm killing or cultivar properties. Alexopoulos *et al.* (1979) showed that when GA3 was applied to potato it induces dormancy breaking, a reduction in specific weight, a higher rate of respiration and increased weight loss during storage.

Stuart and Cathey (1961) shows that hormonal treatments led to the reduction weight of big tubers, but increased the number of smaller tubers. Wareing and Jennings (1980) obtained similar results through their experiments. Also, gibberellic acid had the ability to increase the number of seed tubers. This is explained by the fact that the effect of this hormone on the removal of apical dominance in potato tubers. This has been also proved previously by Racca and Tizio (1968). Gibberellins show different actions at different concentrations, for example gibberellic acid (GA3) avoid tuber fertility at high concentration (Chapman, 2006). The pre-soaking application of gibberellic acid at low concentrations (5 and 10 mg/l) is able to increase the general performance of seed tubers (Wareing and Jennings, 1980). This achievement is very valuable because of two reasons; at first, in seed production programs, any increment of percentage of seed tubers is very important and second, it creates favorable conditions in vogue of tubers in industries by reduction of big tubers and making tubers of equal size. This positive effect of gibberellic acid in increasing seed tuber in potato also has been observed by Alexopoulos *et al.* (1979). Non-significant differences observed in the most parameters between applications of 5 and 10 mg/lit GA3, and increasing the concentration from 5 to 10 mg/lit didn't caused any increase in number and weight of seed tubers and total yield in potato cultivars. Therefore, there is no need to use high concentration of GA3. These results are in conformity with the findings of Lorreta *et al.* (1995). Further, Biemelt *et al.* (2004) indicated that using high level of concentration of gibberellic acid had negative effects on plant production (Table 1).

The sprouting of tubers treated with GA3 was earlier compared to no application of GA3 where the sprouting was very late and slow. When seed potatoes were treated either dormant or sprouted, with various concentrations of gibberellic acid, emergence of plants from treated seed was more rapid than from untreated seed tubers. Wareing and Jennings (1980) proved that the growth of secondary buds in potato stolons, has been intrigued and this phenomenon should be predominant to final dominancy. The sugar content is one of the important parameters determining the sprouting vigor of seed potato, because sucrose, glucose and fructose are known to play a primary role in the metabolism and also during potato growth sugars are required for polysaccharide synthesis and tuberization (Rees and Morrell, 1990).
The foregoing discussions lead to prove a new relationship as follows in Figure 1:

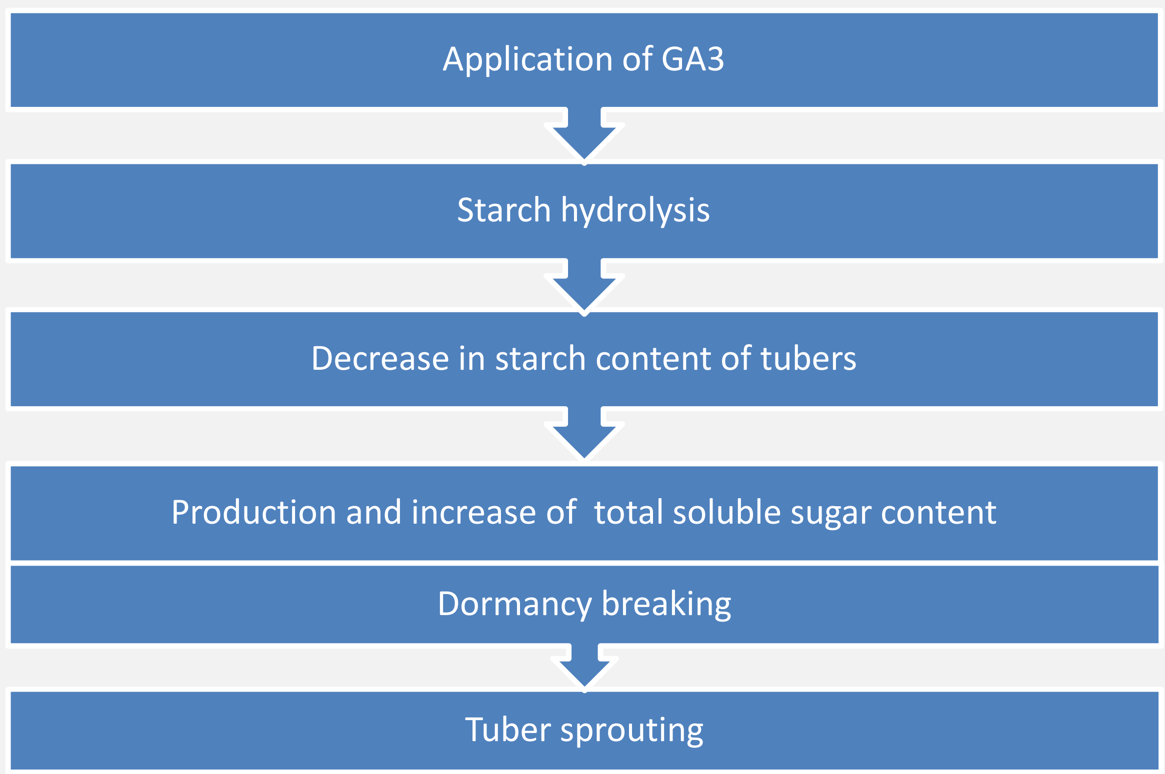

Figure 1 : Application of GA3 and potato growth

Thus, it can be concluded that the application of gibberellic acid increases the productivity of tubers of potato (*Solanum tuberosum* L.). The tubers treated with GA3 sprouted earlier while non application of GA3 sprouted very late and slow. Further, it can also be concluded that one week after application of GA3, the starch fraction started to hydrolyse and increased total sugar content causing the tubers to sprout by breaking dormancy.

1.4. Sulphur

Effect of sulphur application on quality parameters of potato after harvesting are studied by many authors. Jaiswal *et al.* (2008) and Ullah and Saikia (2008) reported differences in quality parameters among different varieties of potato. According ti these authors, tuber yield per plant showed maximum values with 45 kg ha^{-1} sulphur which was significantly superior over control, 15 and 30 kg ha^{-1}sulphur application. However, improvement in tuber yield was not observed with 60 kg ha^{-1} sulphur application. More availability of sulphur, which is an important component in plant nutrition, might have increased the yield in potato upto a limit. It has alson been demonstrated that Sulphur levels showed significant influence on grade wise tuber yield (%) and yield per plant in potato. In fact small size tuber yield (%) was the maximum under control followed by 15, 30, 60 and 45 kg ha^{-1} in descending order. Medium size tuber yield (%) was maximum under 45 kg ha^{-1} followed by 60, 30 kg ha^{-1} sulphur with non significant difference. Highest large size tuber yield (%) was found with 45 kg ha^{-1} sulphur followed by 60, 30 and 15 kg ha^{-1} sulphur application (Table 2).

So there was increase in large size and medium size tuber yield (%) with increase in sulphur level up to 45 kg ha^{-1}, which showed reduction at further high level (Lalitha *et al.*, 2002). However, small size tuber yield (%) recorded reverse trend and showed decrease in small size tuber with increasing doses of sulphur up to 45 kg ha^{-1}. These results are in line with Sud and Sharma (2002) who reported that increase in tuber yield with increasing sulphur levels may be attributed to its role in better partitioning of the photosynthates in the shoot and tubers. Similarly, Lalitha *et al.* (2002) have also reported significant effect on grade wise tuber yield and increase in bulking rate with sulphur application. But heavy applications of sulphur can result in yield reductions. These findings are also in agreement with those of Nasreen *et al.* (2007) in onion.

In addition, Sulphur application increased dry matter content in tuber up to 45 kg ha^{-1}. Thereafter, further increase in sulphur did not showed any remarkable influence. Specific gravity increased with increasing dose of sulphur up to 45 kg ha^{-1}. However, there was no significant difference in specific gravity of tubers under 30, 45 and 60 kg ha^{-1} sulphur levels. Each incremental dose of sulphur enhances the total sugar content in potato tuber up to 45 kg ha^{-1}. Further, increase in sulphur dose recorded slight reduction in sugar content. There was no significant difference in sugar content of tuber at 15 and 30 kg ha^{-1} sulphur as well as 45 and 60 kg ha^{-1}. Starch content was found maximum with application of 45 kg ha^{-1} sulphur which was significantly superior over other sulphur levels. Ramamurthy and Devi (1982) also reported significant increase in dry matter content in tuber with sulphur application. However, they did not find any significant effect on specific gravity, starch and total sugar content. Sulphur deficiency reduced the starch content of potatoes (Eppendorfer and Eggum, 1994). In the same contex, Singh *et al.* (1995) also found significant increase in dry matter content in potato tuber with sulphur application. Sulphur being a component of sulphur containing amino acid as well as involved in sulpho-hydral bonds in polypeptides, also component of protein enzyme involved in chlorophyll, starch and protein synthesis. Involvement of sulphur in these biochemical processes in plant metabolism may be the cause for increased starch synthesis and production of large size tubers (Lalitha *et al.*, 2002). Hence, it may be concluded based on these findings that sulphur has significant influence on yield and quality attributes of potato tubers. Application of 45 kg ha^{-1} sulphur excelled over other doses for both tuber yield and quality attributes.

1. 5. Thiourea

Applying thiourea increased plant height. In addition, using thiourea makes plants germinate faster ; as a result, by decreasing number of days to emergence, plant height increased. Using thiourea increased also significantly number of tubers per plant. According to positive relationship between tuber number per plant with plant height, it seems that strong plants produced more tubers (Mani *et al.*, 2013). Otherwise, Hassan-Pannah *et al.* (2005 ,2007) indicates that no significant difference was observed between using 0.5% of thiourea and control treatment in respect of total weight of tuber per plant. However, they demonstrated that increasing thiourea concentration to 1% increased significantly tuber yield per plant from 183 g to 202 g. So it seems that thiourea increased plant height and also stem number and declined emergence period , leading to increase tuber weight. These findings are in line with those of Rehman *et al.* (2003) and Germchi *et al.* (2011). They mentioned that using thiourea decreased single tuber weight significantly. Although, both tuber number and tuber yield were increased in plant through using thiourea, tuber number per plant had a fast trend or more slope, as a result, single tuber weight per plant was highly decreased and with 1% of thiourea.

According to Hakams *et al.* (2000), application of thiourea increases chlorophyll content and improves photosynthetic assimilation especially when it is applied at 250 mM. Otherwise, the application of thiourea improves chlorophyll content (Figure 2) tuber yield (Figure 3), and number of tubers/plant (Figure 4) especially if it's applied to low concentrations (250 mM) comparion with higher concentrations (500, 750 and 1000 mM) (Figure 2) (Mani *et al.*, 2012). At this concentration, plants produced 20% higher tuber yield than control plants. It's also increases significantly number of tubers per plant. So it seems that increasing the number of tubers is a decisive criteria for increasing the yield of potato. These results are also consistent with the previous findings (Tekalign and Hammes, 2005; Germchi *et al.*, 2011).

2. Influence of the thermal shock and pre-sprouting on potato tuber yield

Physiological ageing advances sprout growth, crop emergence, crop establishment and usually improves tuber yields (Burke and O'Donovan, 1998). However, the onset of the different developmental stages and their duration can be quite different depending on the biological characteristics of the potato variety in question, the quality of the seed tuber, climatic and soil conditions, and the agrotechnical measures employed.

2.1.The influence of pre-planting treatment on potato emergence and number of tubers

Some authors report that physiologically older seed tubers allow for faster emergence than their younger counterparts (Struik and Wiersema, 1999), while others have found no difference (Bus and Schepers, 1978). However the experiments of Eremeev *et al*, (2008) showed that physiologically older seed tubers emerge more slowly. A potato plant usually takes 20-35 days to emerge. The time from planting to emergence depends on the treatment of the seed tubers the physiological age with which they are invested (Jõudu *et al.*, 2002). Intensive tuber growth begins when the aboveground parts of the plant have fully developed although different varieties show significant variations (Putz, 1986). Tuber formation in early varieties usually takes place earlier and growth is much quicker than in late varieties. In addition, plants derived from physiologically older tubers of late varieties begin their tuber formation slightly earlier (Van der Zaag, 1992). Similar findings were reported by Van der Zaag and Van Loon (1987) and Moll (1985).

2.2.The influence of pre-planting treatment on tuber weight

The tuber weight achieved depends on the weather conditions and the available nutrients during the period of tuber formation. It also depends on the growth and development of the leaves and branches, the formation of assimilation products and their distribution between different parts of the plant, the rate of tuber formation, and the perishing time of the haulms (Panelo and Caldiz, 1989). According to Burke (1997), the average weight of tubers increases with their physiological age, this parameter had the strongest influence on tuber weight. According to Putz (1986), after the death of the haulms the growth of the tubers ceases, and the skin hardens and starts to suberize. Decisions taken while planning the harvesting period should not be based on data for years with optimum weather conditions but on average years. At the end of growth period the increase in mean tuber weight occurred mainly at the expense of mean tuber size (35- 55 mm) and the production of large tubers (over 55 mm).

2.3.The influence of pre-planting treatment and variety on yield

According to Möller *et al.* (2001), the duration of yield maturation can be shortened by 8-14 days by the pre-sprouting of seed tubers. With this treatment the time of maximum yield is shifted to about two weeks earlier; yield losses due to potato late blight are consequently reduced. Jõudu *et al.* (2002) established that if harvesting is planned in September, there is no need to thermally treat the seed tubers and bear the extra costs involved, especially if cultivation starts early in the growing season with medium to early varieties. Theses findings show that physiologically older tubers have a higher yield potential, with plants reaching their harvesting point more quickly. Seeds tubers physiologically older allows them to show a higher growth rate and earlier yield maturation than those of the latter treatment. The gradual maturation of the potato yield helps to lengthen the harvesting period even when growing just one variety. Yields per of potato ultimately depend on radiation levels, the agrotechnical measures taken by the grower and the potential of the potato variety. In conclusion, thermal shock would be more efficient in seed tuber production since, while it produces more tubers their mean weight is smaller.

3 . Effect of Production History

Seed potatoes are generally evaluated based on growth vigour and tuber productivity. In addition to cultivar, these characteristics are influenced by the production history.

Temperature sum accumulation increases the physiological age of seed potato. Studies show that physiologically older seed potatoes emerge more quickly than the younger ones (Essah & Honeycutt, 2004; Eremeev *et al.*, 2008). Particularly in short growing season production areas, the quick emergence of seed potatoes accelerates early development of potato growth. Haulm killing or its timing in seed potato production has not previously been observed to have a carry-over effect on the emergence rate of seed potatoes. The present study demonstrates that haulm killing conducted three weeks after flowering accelerates the emergence of seed potato.With regard to the number of stems, the results vary. In most studies, older seed potatoes produce more main stems (Knowles & Knowles, 2006), whereas in the studies by Ezekiel (2004), seed potato age had no influence on stem number. The timing of the temperature sum accumulation increases the number of stems in seed potato, whereas the growing season temperature and daylength do not influence the numbers of seed potato stems or bulk stems (Johansen and Nilsen, 2002; Johansen and Nilsen, 2004). In the present study, naturally maturated seed potatoes produced the most bulk stems and roots and showed physiological behaviour similar to old seed potato. In conditions where the growing season is short, seed potatoes that are older and that have thus experienced a higher temperature sum due to a longer accumulation period are more productive (Ezekiel, 2004). Northern origin or daylength do not affect yield capacity (Knowles & Knowles, 2006; Johansen et al., 2008). On the other hand, haulm killing affects crop yield; for example, Brown et al. (2003) reported that haulm killing conducted three weeks before natural haulm maturing results in increased yield of seed potatoes. In a study by Panelo and Caldiz (1989), haulm killing two weeks before natural maturing did not affect crop yield.

The production history of seed potato can affect the size and number of developing tubers. If the growing season is short, old seed potatoes tend to produce larger tubers than seed potatoes at younger physiological state (Eremeev *et al.*, 2008). Growing season temperature hasnot been observed to have a carry-over effect on the number of daughter tubers produced by seed potato (Johansen and Nilsen, 2004), nor has daylength been found to affect the size of daughter tubers (Johansen *et al.*, 2002). While Holmes and Gray (1972) found no effect of haulm killing on tuber number. The results of the present study are consistent with Wurr *et al.* (2001) indicating that haulm killing does not affect the size or number of tubers produced.

4 . Effect of light

To assess the impact of solid-state lighting spectral composition on the germination of potato tubers, the quantitative method was applied to determine the number and percentage of germinated shoots in the upper, middle and bottom parts of tubers, the weight of tubers (g and %), sugar content and composition in potato tuber shoots and in shoot areas. Studies have shown a positive effect of the spectral composition of light on potato tuber germination. Irradiated tubers shaped short, compact buds. If potato tubers were kept in the dark, their buds were pale yellow in colour and brittle. The greatest inhibition of apical domination in potato tubers was observed at the solid-state lighting spectral composition of blue 445 nm, red 638 nm and red 669 nm light. The total maximum number of germinated shoots was observed at the solid-state lighting spectral composition of blue 445 nm and red 638 nm light. The impact on the germination of potato tubers was negative at the solid-state lighting composition with UV 385 nm. A higher sugar content was found in the apical buds of tubers that had been kept in the dark because of a more intensive transport of assimilates. Sugar content in buds and bud growing areas directly depended on the intensity of sprouting (Juknevičienė *et al.*, 2011)

Otherwise, green light would have provided favorable irradiance (24% of white fluorescent) for tuber induction. Since white light provides a range of wavelength, with peaks in the blue, green and red regions (Aksenova *et al.*, 1994, Mohamed-Ali, 2011), tuber development seems to require more than one spectrum. Red light stimulated stolon formation, perhaps through increasing GA biosynthesis (Goeden and Tong, 2003; Seabrook, 2005). Exposing plantlets to white, followed by green or blue light for 4 weeks positively affected their subsequent tuberiz ation in the dark. These light pre-treatments resulted in enhanced plantlets growth performance which might have led to their increased tuberization potentials. Protein banding pattern revealed the presence of patatin bands in all microtuber samples with high er abundance under red light than those lightcolor s found to increase microtuberization. Miyashita *et al.* (1997) Kim and Lee (2004) and also showed that a 90% reduction of patatin content in tuber had very little effect in tuberization.Therefore, the relation between light quality and patatin occurrence await further studie.

For microtubers, it was observed that complete obscurity was an essential factor in tuber induction. Cultures kept under 16 hrs., photoperiod were not able to produce microtubers. During incubation under light, GA3 is synthesized which inhibits tuber induction while darkness enhanced tuberonic acid synthesis, which plays important role in tuber formation. Tuberonic acid is a glucoside of 12-hydroxil-Jasmonic acid involved in tuber induction as reported by Juknevičienė *et al.*, (2011). Dobranszki *et al.*, (1999) and Donnelly *et al.*, (2003) have also demonstrated that microtuberization efficiency has been increased by short day's exposure or continuous darkness during culture condition. Similarly Zaida and Elizabeth (1991) have reported that shoots grown under 16 hrs photoperiod when placed under darkness induced tuber formation.

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