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Review on dry matter production and partitioning as affected by different environmental conditions

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Abstract

Environmental requirements for the satisfactory growth and development for tropical crops have been less studied. Amongst environmental factors, temperature, water stress, salinity, photoperiod, and fertilizer/Nitrogen/ are considered a primary determinant of plant development and dry matter production and partitioning of the crop. The plant decrease in root and shoot weight at high temperature increased leaf senescence and decreased dry matter production and partitioning. The long and short photoperiod affect the plant dry matter production and partitioning, long photoperiod, resulting in smaller tubers and low harvest index. The plants grown under short photoperiod, in contrast, had low number of tuber and high harvest index. This was possibly due to the effect of short photoperiod that promotes partitioning of assimilates to harvestable tubers .Short photoperiod (11 hours) reduced stem length, stem dry matter and leaf growth, induced stolon and tuber growth and enhanced senescence, whereas long photoperiod (14 hours) promoted leaf and stem growth, but it delayed stolon and tuber on depending on plant. Availability of higher nitrogen stimulates greater nitrogen uptake which accelerates cell division, resulted in higher leaf and tiller numbers that leads to increased dry matter production. Moisture stress at booting and flowering reduces plant height and dry matter production, delays panicle exertion, and induces uneven flowering. Leaves of salt stressed plants frequently contain unusually high concentrations of sugars as a result of the effects of the stress on the phloem translocation or on reduced sink size because of reduced growth. Generally, from this review of the literature we can conclude that the environmental factor greater influencing the growth and development of plant organ by seriously affecting the dry matter production and partitioning

Keywords: Dry matter production, dry matter portioning ,Environmental factor

1. Introduction

Variability in plant development may be due to different management practices and different environmental conditions. Environmental requirements for the satisfactory growth and development for tropical crops have been less studied (Squire, 1990). Amongst environmental factors, temperature is considered a primary determinant of plant development. Temperature plays a central role in controlling crop emergence as well as leaf initiation and appearance rate (Miglietta et al., 1995). Optimal crop growth requires a continuous supply of water, nutrients and radiation; as temperature rise, the demand for growth resources increases due to higher rates of metabolism, development and evaportansiparation (Martiniello and Teixeira da Silva, 2011). When growth resources are limited by high temperature, the size of plant organs such as leaves, tillers and spikes, is reduced. The sensitivity of metabolic processes to high temperature coupled with the reduced length of life cycle, results in low grain yield (Hossain et al., 2012). Similarly, (Slafer and Rawson, 1994) suggested that since plant development is a progression of responses to the environment there must be historic as well as current effects of the environment on crop development. For example, (Vincent and Gregory, 1989) found more tillers at 12°C than at 25°C in winter wheat, (Przywara and Stepniewski ,1996) observed decrease in root and shoot weights at high temperature, and (Asseng et al., 2011) noticed that high temperature increased leaf senescence and decreased grain filling.

Plant water status determined dry matter production (i.e. photosynthesis) and its partitioning between the different organs of the plant. Dry matter partitioning to permanent structures was greater under water stress than under non-water stress conditions. However, the effect of water stress on dry matter content and partitioning should not be generalized for all plan . The different cultivar of the crop and its interaction with irrigation were found not always to have a significant effect on most of the measurements taken in this experiment. Water stress modified the periodical accumulation of dry matter. Total dry matter was reduced between pruning and fruit set under non water stress conditions but increased slightly under water stress conditions (Marial et al., 2004)

Availability of adequate soil moisture prolonged total dry matter production but reduced the proportion of dry matter allocated to storage roots (Enyi, 1977). An increase in N and K fertilizers considerably increased total dry mass and storage root dry mass (Bourke, 1985; Li & Yen, 1988). An increase in plant population decreased storage root dry matter and shoot dry matter per plant but significantly increased yield per hectare (Li & Yen, 1988).

Water-deficit commonly occurs during the growing season and the intensity of stress depends on the duration and frequency of water-deficit. The drought pattern is complex in rainfed lowlands, as drought may occur early in the growing season or any time from flowering to grain filling and may follow a period when soils were flooded and anaerobic (Wade, 1999). Drought stress suppresses leaf expansion, tiller and midday photosynthesis (Kramer and Boyer, 1995) and reduces photosynthetic rates and leaf area due to early senescence (Nooden, 1988). All of these factors are responsible for a reduction in dry matter accumulation and grain yield under drought. The productivity of crops depends not only on the accumulation of dry matter, but also on its effective partitioning to plant parts of economic importance and this is a key to yield stability particularly under drought stress. Remobilization of reserves to grain is critical for grain yield if the plants are subjected to water stress during grain filling (Nicolas et al., 1985; Palta et al., 1994; Ehdaie and Waines, 1996).

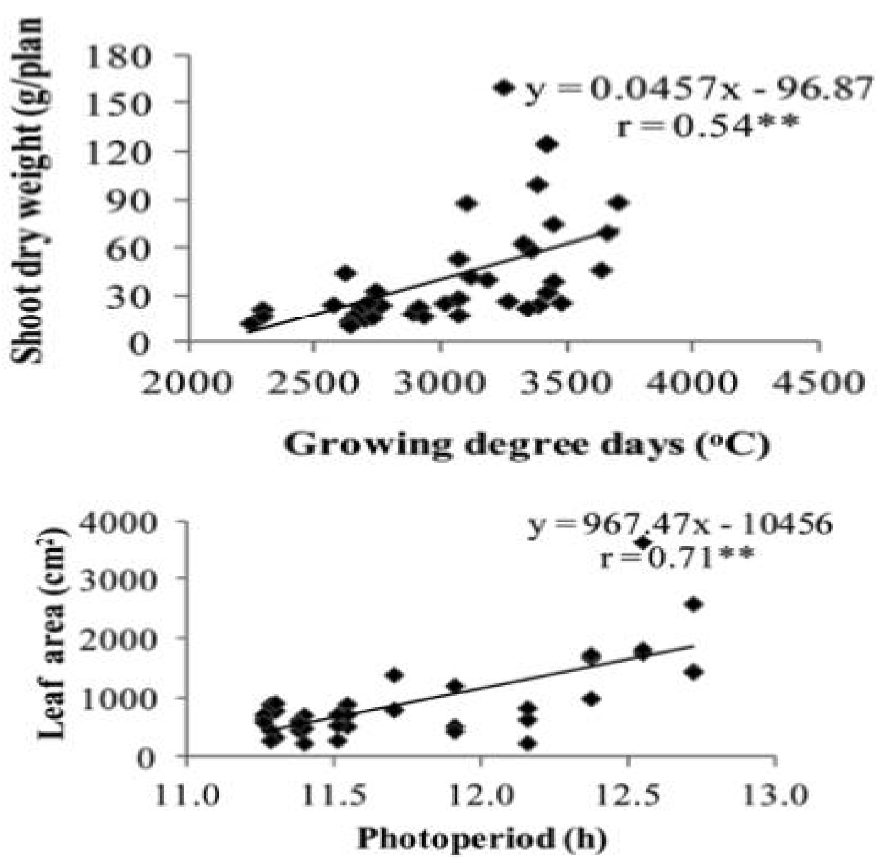
Among plant nutrients nitrogen has been considered as a major growth and development element (Ericssion, 1995; Nikolic et al., 2012). Waraich et al., 2002) observed that increased N results in maximum leaf area index at tiller and booting stages, number of tillers, net assimilation rate, relative growth rate, grain weight and grain yield. Nitrogen is responsible for shoot and root growth (Comfort et al., 1988) grain formation (Arduini et al., 2006) and protein synthesis (Casagrande et al., 2009; Acreche and Slafer, 2009). Nitrogen stress restricted growth 0f plants (Semenov et al., 2007) and their dry matter production (Arduini et al., 2006). High nitrogen treatment increased the number of tillers (Palta and Filley, 1995; Maqsood et al., 2012) and shoot dry matter (Laghari et al., 2010). There are conflicting reports in the literature about the effects of nitrogen supply on the rate of leaf emergence of cereals. Muchow (1988) found that the rate of leaf emergence was lower at low nitrogen in sorghum, and similar results have been found in barley (Dale and Wilson, 1978). However, Bauer et al., (1984) found no effects of nitrogen on the number of leaves in spring wheat. However, Latiri et al., (1998) reported that nitrogen stimulated dry matter production substantially due to increased leaf area index, which resulted in improved efficiencies of radiation and water use. Effects of nitrogen on leaf development and growth of Spinach were described by (Biemond , 1995). More nitrogen increased the total green leaf area mainly by increasing the site of individual leaves this result from an increased in the rate of leaf expansion. soil salinity is the most dominant factors limiting crop production in the saline areas of during dry season, salt tolerant crop can bring substantial changes in the agricultural practices in that problem soils (Zeman et al.,2015). Salinity reduces growth and yield of non-halophyte by decreasing the availability of water to the roots due to the osmotic effect of external salt and by creating toxic effects of excessive salt accumulation within the plant (Hayat et al. 2011) . Salinity occurs through natural or human induced activities that result in the accumulation of soluble salt in soil and the problem of soil salinity expected to boost in future with the progress of desertification process and greenhouse effect (Singh et al., 2001). So that, the objective paper to review the effect of environmental factor on dry matter production and partitioning of crop.

2. Literature Review

2.1 Photoperiod

As Sanun et al., (2013) studied there is strong correlation between photoperiod and growing degree day indicated that these factors had synergistic and significant effects on the growth, biomass production ,total biomass and yield of Jerusalem artichoke. The results of this study are in agreement with previous findings made on other crops. Warm day/night temperature of 32/22 oC during day and photoperiod of 16 hours increased plant height and leaf numbers while translocation of photosynthetic to the tubers of potato was low under these conditions (Wolf et al., 1990). Similarly, warm day/night temperature of 30/24 oC and photoperiod of 18 hours delayed the onset of tuber growth and the onset of tuber bulking (Van Dam et al., 1996). Higher temperature and longer photoperiod gave lower relative rates of partitioning of dry matter to the tubers.

The effects of growing degree days and photoperiod on partitioning of assimilates were in the same direction because these factors were closely associated to plant growth. These findings were rather similar to those made for other tuber crops such as potato. In potato, high temperatures reduces the allocation of photosynthetic to the tubers in detriment of biomass and long photoperiod delays maturity at high temperatures because plants will be so poorly induced to tuberose that tuber will form much later than normal and new leaves will continue to form over a longer period of time. Potato plants that were exposed to short photoperiod showed reductions in leaf area, branching and root growth. However, assimilate allocated to root growth was increased (Ewing and Sandlan, 1995). In cassava, short days increased root growth and reduced vegetative growth and the development of roots. Long photoperiod increased shoot growth and reduced carbohydrates available for root growth (Lebot, 2009)



Source: - Spring 2013 Available on line www.Agriculture and Biosystem Engineering

Figure 1. Relationship between shoot dry weight (g/plant) and leaf area on (a) photoperiod

Maturity in the temperate regions (approximately 8 months) is generally longer than in the tropics (approximately 4 months) because crop growth rates near the Equator are faster (Kay and Nottingham, 2008). In temperate regions, some late maturing genotypes do not flower because the stems are killed by early frost (Denoroy, 1996). As (Sanun et al., 2013) studied in contrast, some early maturing genotypes did not flower during the shortest photoperiod. The crop stops vegetative growth earlier and tuber initiation starts sooner than in more northerly latitudes, resulting in shorter plant and smaller tubers (Kay and Nottingham, 2008)

In multi-location trials, Pimsaen et al., (2010) found that the contribution of location and seasonal effects was significant on tuber yield, tuber number and tuber size. Differences in planting dates significantly affected growing degree days, photoperiod, total biomass, shoot dry weight, leaf area, tuber dry weight, harvest index, number of tubers per plant and weight of individual tubers, indicating that growing degree days and photoperiod played an important role on the growth performance of these traits.

The number of tubers was generally increased with Growing degree days, whereas weight of individual tuber was reduced. The plants showed highly prolific solons under high growing degree days and long photoperiod, resulting in smaller tubers and low harvest index. The plants grown under short photoperiod, in contrast, had low number of tuber and high harvest index. This was possibly due to the effect of short photoperiod that promotes partitioning of assimilates to harvestable tubers (Soja and Dersch, 1993)

In temperate regions, short photoperiod of 13 hours generally increases harvest index of Jerusalem artichoke (Denoroy, 1996). Short photoperiod is also a favorable condition for the initiation of flowers and rapid tuber growth (Meijer and Mathijssen, 1991). Short photoperiod (11 hours) reduced stem length, stem dry matter and leaf growth, induced stolon and tuber growth and enhanced senescence, whereas long photoperiod (14 hours) promoted leaf and stem growth, but it delayed stolen and tuber. Since short photoperiod can severely reduce growth but increase harvest index and tuber size, the planted at higher plant population density in the winter season when temperature is low and photoperiod is short. In winter wheat, (Sun et al., 2013) reported that sowing time and rate affected biomass accumulation. The optimized sowing time and sowing rate has the potential to improve yield of winter induction (Soja and Dersch, 1993).

2.2 Nitrogen

AS (Karimil et,al., 2013) founded that high nitrogen significantly increased total dry weight , shoot dry weight , number of leaves on main stem , number of tiller per plant and number of leaves per tiller as affected by temperature . However, plants of same cultivar received low nitrogen significantly increased root dry weight (33% at 20°C and 5% at 15°C).The research done by (Nikolic et al., 2012) on Wheat plant received high nitrogen significantly increased total dry weigh, shoot dry weight, number of leaves on main stem , number of tiller per plant and number of leaves per tiller as affected by temperature . Root dry weight response of was higher (22%) in high nitrogen concentration (6 mM) at 15°C however at 20°C low nitrogen increased root dry weight by 9%. This indicated that plant growth and development depend on nitrogen supply and in general increasing the nutrient enhances plant growth and development (Bauer et al., 1984; Nikolic et al., 2012). The nutrient supply and demand of root and shoot are inter-dependent due to their different functions and local environment (Li et al., 2001; Arduini et al., 2006; Hakim et al., 2012). Karimil et al., (2012) research was supported as high nitrogen increased shoot, root and total dry matter. This contrasts with Muchow (1988) who found fewer leaves in low nitrogen treatments in sorghum. The difference might be due to the difference in species. Relationships between the number of tillers and shoot dry weight were not the same at high and low nitrogen in both cultivars. There were more tillers at high nitrogen in both cultivars when compared shoot dry weight however it appeared as temperature dependent (Altenbach et al., 2003). Similarly, the relationship between the number of leaves on tillers and shoot dry weight showed more leaves of both cultivars at high nitrogen , and fewer leaves at low nitrogen for shoot dry weight. These results are in line with Dale and Wilson (1978) and Maqsood et al, (2012) who reported that high nitrogen increased leaf numbers in wheat. Plant organ development depends on nitrogen supply which is required for their induction (Nikolic et al., 2012). It is a constituent of proteins, nucleic acids and chlorophyll. Its compounds comprise about 50 per cent of the dry matter content of plant cells. Availability of higher nitrogen stimulates greater nitrogen uptake which accelerates cell division, resulted in higher leaf and tiller numbers (Arduini et al., 2006)

2.3 Temperature

The rate of organ initiation appears to be closely related to growth by the response of cell division to temperature (Farrar and Gunn, 1996). Generally, three ranges of temperature affect plant growth parameters. In the first range, growth and development rate increase with temperature, in the second optimal range, the process does not respond to temperature, and third range is supra optimal, where the development rate decreases as temperature increases (Loomis and Connor, 1992; Martiniello and Teixeira da Silva, 2011). Kocsis et al., (2007) and Kocsis et al., (2008) found that shoot dry weight was increased with high temperature sums (growing degree day) in temperate regions. Accumulation of above ground biomass requires high heat unit, however, Tsialtas and Maslaris (2008) reported that high temperatures (35-37 oC) degraded leaf chlorophyll and repress photosynthesis of sugar beet in the temperate climate.

2.4 Moisture stress

Drought is defined as the condition in which soil water is insufficient to ensure maximum plant growth (Ghildyal and Tomar, 1982). On a global basis, drought limits plant growth and crop productivity more than any other single environmental factor (Boyer, 1982 as edited by Jones, 1989). Hale and Orcutt (1987) define drought is a meteorological term that means a lack of precipitation over a prolonged period of time.

Moisture stress at booting and flowering reduces plant height and dry matter production, delays panicle exertion, and induces uneven flowering. Photosynthetic efficiency is impaired, resulting in less dry matter accumulation and a low concentration of non reducing sugar in the stem (Bhattacharjee, 1971 as cited by Murty, 1982). In general, varieties with high dry matter production at flowering gave better yields under dry land condition because of a considerable contribution of reserve carbohydrates to grain filling (Murty, 1978 as cited by Murty, 1982)

The research done by Kumar et al., (2005) that water availability at reproductive stage significantly influenced post-flowering of dry matter production. Differences were observed among maturity groups and cultivars in terms of dry matter production and its partitioning under favorable and unfavorable conditions. Late-maturing cultivars produced higher dry matter at maturity under favorable conditions, presumably, because their photosynthetic activity continued for a longer duration in the presence of sufficient soil moisture. The higher leaf relative water content at flowering along with a shorter delay in flowering, which helped in maintaining its dry matter production after flowering and stabilized its grain yield under severe drought- stress conditions. A negative association between leaf water potential and delay in flowering has been reported under upland and lowland stress conditions in rice (Sibounheuang et al., 2001), with a longer delay in flowering taken as an indication of a cultivar's susceptibility to drought (Pantuwan et al., 2001). The results on dry matter redistribution showed that contribution of dry matter partitioning from stem and leaves increased significantly under water-deficit conditions compared with well-watered conditions. This result was compatible with the hypothesis that water-deficit promote remobilization of assimilates to panicles for increased grain yield under stress. In wheat, Yang et al., (2001) reported that 75–92% of pre anthesis Carbon stored in the straw was reallocated to grains under water stress, 50– 80% higher than the amount remobilized under well- watered conditions. As Yang et al., (2003) reported in his research the water-deficit during grain filling enhanced whole plant senescence and such enhanced senescence can facilitate remobilization of carbon reserves, accelerate grain filling and increase grain yield under drought. Delayed senescence during grain filling under drought-stress conditions can result in more non-structural carbohydrate remaining in the straw, leading to a lower harvest index (Zhu et al., 1997; Wang et al., 1998; Chen, 2001; Gu and Tang, 2001). The capacity to maintain leaf water potential during drought stress seems to be important for yield stability in drought-prone environments (Jongdee et al., 2002). Water stress determined structural organ dry matter and partitioning at harvest. At harvest, irrigation treatment had a greater influence on root dry matter than on wood dry matter. Water stress caused a 45 % and 28 % reduction in root and wood dry matter respectively compared irrigation field. Mullins *et al.*, (1992) found that roots were more affected than wood when was irrigated as compared. The research done by Barvodo et a., (1992) shoot and leaf dry matter accumulation and partitioning higher in the no water stress cultivation than in the water stress and shoot is the plant organ mostly affected water stress. Fruits is of the organs most affected by water stress. Fruit dry matter accumulation was 65 % lower in the water stress than in the non water stress treatment throughout the season. Depending on the level of water stress, this reduction could be due to fruit set reduction, lower sugar concentration and smaller bunches (Smart and Coomb, 1983; Williams *et al*., 1994)

The interaction between plant water status, delay in flowering, plant senescence and remobilization of assimilates from vegetative parts to grains warrants further investigation using cultivars that are similar in plant size and growth duration, but differing in response to drought stress. The basis for the expression of stay-green traits and any association between rapid green leaf senescence and lodging

2.5 Salinity

According to Yoshida (1981), salinity is defined as the presence of excessive concentrations of soluble salts in the soil. Major ionic species of salts are sodium, calcium, magnesium, chloride, and sulphate. Among those, sodium chloride is predominant. Saline soils normally have a pH lower than 8.5 and an electric conductivity of the saturation extract greater than 4 mtnho/cm at 25 °C. The reaction mechanisms of plants under drought and salt stress can be divided conveniently into three categories: phonological, morphological, and physiological. Salt stressed plants often look like small dark green leaves, decreased shoot-root ratios, decreased tiller, prolonged dormancy of lateral buds, delayed and reduced flowering, and fewer and smaller fruits (Hewitt, 1963 as cited by Hale, 1987). Leaves of salt stressed plants frequently contain unusually high concentrations of sugars as a result of the effects of the stress on the phloem translocation or on reduced sink size because of reduced growth (Gauch, 1942; Nieman, 1976; Strogonov, 1962 as cited by Hale, 1987). The dry weight of all plants in saline water was less than that of plants in fresh water. Leaf area of plants in saline water smaller resulting in small leaf dry weight compared with that of plants in fresh water, so that the smallest dry matter yield in plants with saline water.

Salinity induced differences in total dry matter production among the genotypes were caused by the differences in the reduction of root, leaf, and stem dry matter over their control. Dry weight per plant was adversely affected by increasing levels of salinity. Reduction in total dry matter accumulation under saline condition was also reported by Neelam et al., (2010) and Shamsul et al., (2011) in Indian mustard (Brassica juncea) and Memon et al., (2010) in Brassica campestris L. The research done by Kripa et al., (2011) the poor seed yieldunder saline environment was attributed to salt induced shrinkage and even complete damage of chloroplast, decrease in photosynthetic in the phloem and water deficiency in the growing region (Flowers et al, 1991). According to Ashraf et al., (1999) the reduction in seed yield may also be due to decreasing assimilates production associated with decreased plant size and yield**.** *It was reported* that salt stress caused low photosynthesis (Pn) which was associated with a low demand for photosynthetic in the sink (Sultana et al., 1999). The less reduction in photosynthesis of tolerant genotypes at high salt concentration than susceptible group might have contributed to maintain better growth through shoot dry matter production in the genotype maize **(**Zamanet et al., (2015)

Table 1. Morphological characters of plant before salinity stress

	LAI (m2/m2)	LAR (m2/g)	LWR (g/g)	SLA (m2/g)	SLW (g/m2)	Number of tillers	Plant height (cm)	Stem height (cm)
Fresh water	1.182 *	0.0137	0.407	0.0338	29.667 *	3.95*	111.1*	36.6
Saline water	0.929	0.0154*	0.399	0.0393*	25.953	3.60	106.9	36.4

LAI, leaf area index, LAR leaf area ratio, LWR leaf wehight ratio, SLA, specific leaf area, SLW, specfic leaf weight
Source: Le Thanh Phong, Available on line www. Department of Theoretical Production Ecology Wageningen Agricultural University on Janauary, 2019

3. Summary and Conclusion

Variability in plant development may be due to different management practices and different environmental conditions. Environmental requirements for the satisfactory growth and development for tropical crops have been less studied (Squire, 1990). Amongst environmental factors, temperature, water stress, salinity, photoperiod, and fertilizer/Nitrogen/ are considered a primary determinant of plant development and dry matter production and partitioning of the crop. The plant decrease in root and shoot weight at high temperature increased leaf senescence and decreased dry matter production and partitioning. The long and short photoperiod affect the plant dry matter production and partitioning, long photoperiod, resulting in smaller tubers and low harvest index. The plants grown under short photoperiod, in contrast, had low number of tuber and high harvest index. This was possibly due to the effect of short photoperiod that promotes partitioning of assimilates to harvestable tubers .Short photoperiod (11 hours) reduced stem length, stem dry matter and leaf growth, induced stolon and tuber growth and enhanced senescence, whereas long photoperiod (14 hours) promoted leaf and stem growth, but it delayed stolon and tuber on depending on plant. .The fertilizer effect on dry matter production related with high nitrogen significantly increased total dry weight , shoot dry weight , number of leaves on main stem , number of tiller per plant and number of leaves per tiller. Availability of higher nitrogen stimulates greater nitrogen uptake which accelerates cell division, resulted in higher leaf and tiller numbers that leads to increased dry matter production. Moisture stress at booting and flowering reduces plant height and dry matter production, delays panicle exertion, and induces uneven flowering. Photosynthetic efficiency is impaired, resulting in less dry matter accumulation and a low concentration of non reducing sugar in the stem. Salt stressed plants often look like small dark green leaves, decreased shoot-root ratios, decreased tillering, prolonged dormancy of lateral buds, delayed and reduced flowering, and fewer and smaller fruits . Leaves of salt stressed plants frequently contain unusually high concentrations of sugars as a result of the effects of the stress on the phloem translocation or on reduced sink size because of reduced growth. Generally, from this review of the literature we can conclude that the environmental factor greater influencing the growth and development of plant organ by seriously affecting the dry matter production and partitioning

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