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Crop Production and Global Warming

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1. Introduction

Crop production will be affected by global warming, resulting in world-wide food shortages and starvation. Increased concentrations of carbon dioxide (CO_2), one of the main substances responsible for global warming, will promote plant growth through intensified photosynthesis. Some reports indicate that a rise in the levels of CO_2 would actually benefit plants, rather than harm them. The growth rates of C_3 plants increase in response to elevated concentrations of carbon dioxide. Thus, global warming might increase plant growth, because of higher temperatures and higher levels of atmospheric CO_2.

High atmospheric temperatures caused by elevated concentrations of CO_2 will induce heat injury and physiological disorders in some crops, which will decrease the incomes of farmers and agricultural countries. Photosynthesis is one of the most sensitive physiological processes to high temperature stress. Reproductive development is more sensitive than vegetative development to high temperatures, and heat-sensitivity differs among crops. In tomato, the optimal temperature for fruit set was reported as 21–24°C (Geisenberg and Stewart, 1986) or 22–25°C (Peet and Bartholomew, 1996), while pollen viability and release are adversely affected by high temperatures, and become major limiting factors for fruit set. Thus, global warming can have opposite effects on plant growth. From a long-term viewpoint, however, high atmospheric temperatures will drive the main sites of crop production further north, establishing new rules for the 'right crop for right land'.

Water shortages caused by global warming will be the greatest problem for crop production. Plants fundamentally rely on adequate fresh water, and agricultural water accounts for 70% of water use world-wide. As higher temperatures increase evaporation from water sources and decrease precipitation, arid regions will become further desertified. Particularly in semiarid regions, the cultivatable area will decrease because of drought, and this could result in famines and mass migration. As well, it is likely that there will be human conflicts over irrigation water and food.

Global warming is thought to be related to strong hurricanes, cyclones, and typhoons. These extreme weather events can seriously damage crop production, and destabilize farm management and the lives of consumers. However, these agricultural problems are most likely to occur in the medium and long-term future.

In this chapter, we summarize some of the agricultural problems and crop damage that result from global warming, and present some technical countermeasures (not political and administrative countermeasures) that could be used to ameliorate the effects of global warming on crop production. We also discuss parthenocarpy and grafting as potential countermeasures.

2. Effects of global warming on plant growth

2.1 Carbon dioxide

Carbon dioxide is a key molecule for photosynthesis. In plants, photosynthesis occurs mainly in the leaves. The chemical reaction driven by solar energy involves the reduction of CO_2 through water to create carbohydrates and release oxygen. The resulting carbohydrates are used for plant growth, and provide the energy source for living things. Under 'normal' conditions, the atmospheric CO_2 concentration is very low. The photosynthetic reactions under high temperatures and high light intensities are limited by the CO_2 concentration, and the photosynthetic rate does not exceed a certain value. Because CO_2 is the limiting factor, an increase in its concentration significantly affects photosynthesis. In general, increased CO_2 concentrations temporary promote photosynthesis; however, the photosynthetic rate decreases over an extended period of exposure to high CO_2 concentrations.

Photosynthesis is affected by various environmental conditions. In appropriate temperature conditions, the photosynthetic rate with the current CO_2 concentration of 370 ppm is strongly influenced by light intensity. Under low light conditions, the photosynthetic rate and the light saturation point are low, and so the CO_2 requirements are low. However, at higher light intensity, the photosynthetic rate and light saturation point are higher (Fig. 1). Thus, CO_2 is one of the major environmental factors affecting plant growth along with light, temperature, and water. However, unlike other environmental factors, the CO_2 concentration in the atmosphere does not fluctuate with climate change. Apart from anthropogenic sources, natural causes of changes in the atmospheric CO_2 concentration include plants, which at high density can change the CO_2 concentration by 25%, and respiration of soil microbes, which can change the CO_2 concentration by 30% near the soil surface.

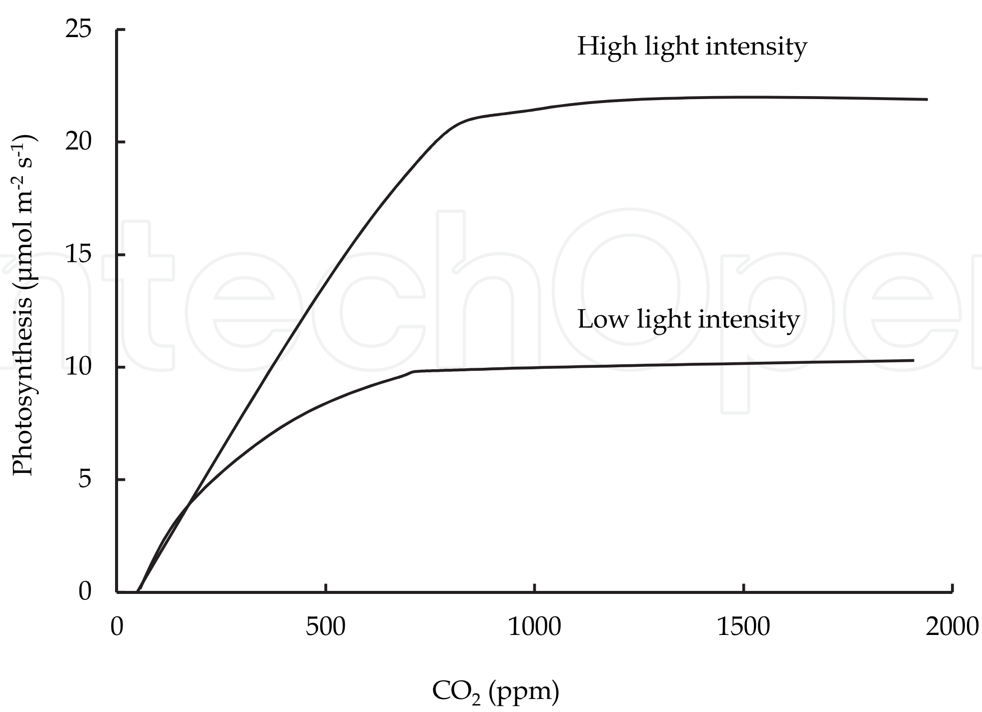

Fig. 1. Photosynthetic curves at high and low light intensities.

In plants, the promotion of photosynthesis under high CO_2 concentrations results in increased dry matter production. This is known as the "CO_2 fertilizer effect", and it is used to promote crop growth in greenhouses and plant factories. This effect is more pronounced in C_3 crops, such as wheat, soybean, and rice, but less so in C_4 crops, such as maize, millet, and sugarcane. This is because the current atmospheric CO_2 concentration limits photosynthesis in C_3 plants, but not in C_4 plants because of their ability to concentrate CO_2 in the cells (Fig. 2). If the concentration of CO_2 is doubled, the photosynthetic rate of many C_3 plants increases by 30–60%, but in most C_3 plants these promoted rates are temporary, and there are no promotion effects in the long term. Thus, it is thought that the changes in the photosynthetic apparatus or other photosynthetic factors that occur during short-term responses to increased CO_2 differ from those during long-term exposure to increased CO_2. This phenomenon often occurs when photosynthetic production exceeds plant growth (Nakano et al., 1997; Makino, 1994).

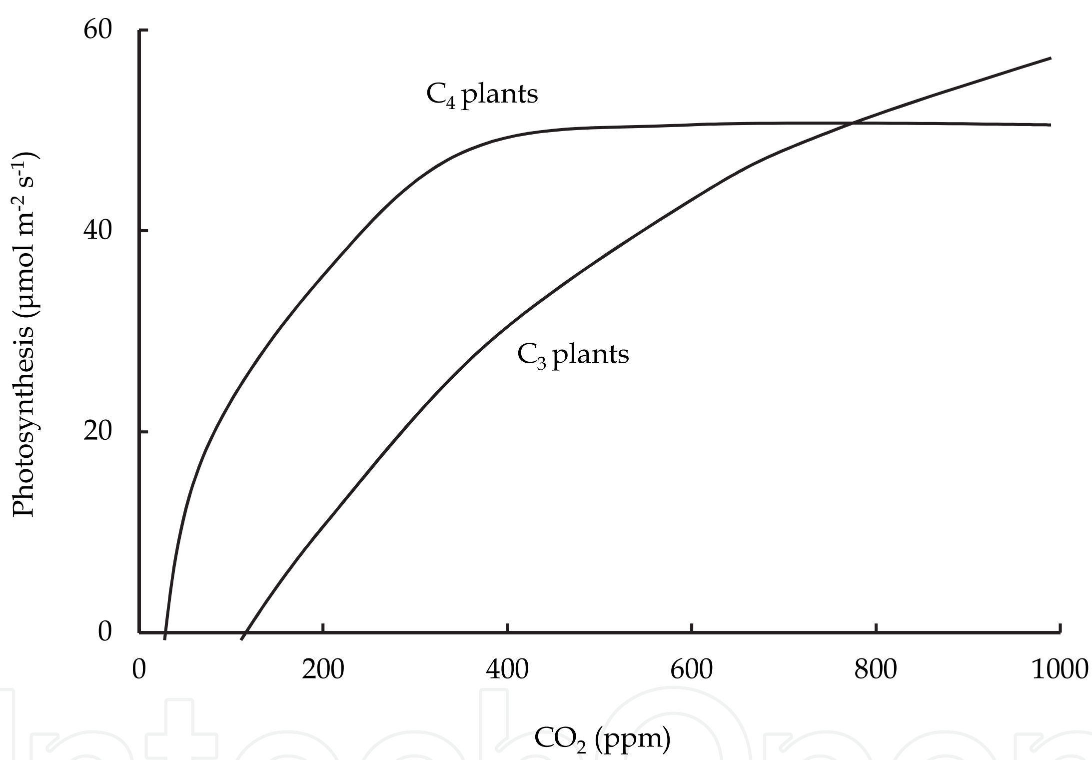

Fig. 2. Photosynthetic curves for C3 and C4 plants (Rogers &Runion, 1994).

The effects of CO_2 concentration on crop yield will become greater as the atmospheric CO_2 concentration increases. For many crops, the predicted yield increase in response to a 700 ppm CO_2 concentration is approximately 30%; specifically, a yield increase of 31% in wheat (Amthor, 2001), 29–35% in rice (Cock and Yoshida, 1973; Imai et al., 1985) 55% in soybean (Rogers et al., 1983), and 50% in maize (Rogers et al., 1983). However, the promoting effects will vary according to the specific nature of the plant and its sinks, e.g., seeds or bulbs. Even though photosynthesis in C_3-type crops is generally inhibited by long-term exposure to high CO_2 concentrations, those that have separate organs to accumulate photosynthetic products appear to be unaffected. For example, inhibition of photosynthesis in crops such as radish and potatoes has not been observed (Sage et al., 1989; Usuda and Simogawara, 1998). Also, if water and mineral nutrients become limiting factors, the promoting effects of increased CO_2

concentration on crop production are minor. This may because there is insufficient water and mineral nutrients to support an increase in photosynthesis, because of the balance of growth between the root and the shoot.

2.2 Temperature

Crop germination and growth rely on optimal temperatures during the period of greatest growth rate. Therefore, non-optimal temperatures slow the growth rate or stop growth altogether. The limiting temperatures for growth are minimum and maximum temperatures, and these vary among crops (Table 1), crop varieties (Table 2, Prasad et al., 2006), and among different growth stages in the same crop. In particular, temperature strongly affects crops during their reproductive period, from pollen formation to fertilization (Table 3). Low or high temperatures during this period can prevent crop fertilization and cause seed abortion.

Temperature type	Crops	Germination (°C)			Growth (°C)		
		Optimum	Min	Max	Optimum	Min	Max
High	Eggplant	20-25	15	33	22-28	17	33
	Pepper	20-30	15	35	25-30	15	35
	Water Melon	25-30	15	35	25-30	13	35
	Melon	25-30	15	40	25-30	18	35
	Soybean	25-30	10	35	25-30	10	35
	Maize	25-30	10	40	20-30	10	35
Midle	Wheat	25-30	2	40	20-25	4	30
	Tomato	15-27	11	30	21-26	5	35
	Cucumber	25-30	18	30	18-25	12	35
	Pumpkin	20-25	15	40	17-25	10	35
Low	Lettuce	15-20	4	25	15-20	8	25
	Carrot	15-25	11	30	16-20	5	28
	Potato[z]	-	-	-	15-24	10	29
	Strawberry[z]	-	-	-	17-23	10	23
	Cabbage	15-30	8	35	15-20	5	25
	Spinach	15-20	5	30	15-20	3	25

[z]: Potato and strawberry are mainly vegetatively propagated.

Table 1. Temperatures for germination and growth of crops (recasting and adding of Saitoh, 2008).

	Vegetative biomass (g $plant^{-1}$)			Grain yield (g $plant^{-1}$)		
	AT	HT	% decrease from AT	AT	HT	% decrease from AT
L-204	11.9	12.3	0.0	11.9	1.3	89.1
M-202	12.0	10.6	11.7	13.6	1.9	86.0
Labelle	22.7	12.3	45.8	21.8	4.5	79.4
Italica Livorma	8.7	11.6	0.0	12.5	1.4	88.8
S-102	9.2	9.6	0.0	15.3	1.6	89.5
Koshihikari	9.1	9.9	0.0	12.3	2.7	78.0
M-103	8.7	9.3	0.0	12.2	4.4	63.9
N-22	17.4	23.8	0.0	17.7	9.2	48.0
IR-8	17.7	11.2	36.7	8.2	6.2	24.4
IR-72	15.9	12.6	20.8	8.4	5.5	34.5

Table 2. Effects of ambient temperature (AT) and high temperature (ambient +5 ºC, HT) on vegetative biomass and grain yield of different rice cultivars (Prasad et al., 2006).

Crop	High-temperature injyury
Wheat	Male serarity (over 30 ºC)
Tomato	Male serarity (over 30 ºC)
Cucumber	Male serarity (over 30 ºC)
Pumpkin	Abnormal differentiation of male and femal flower (over 30ºC)
Potato	Poor potatp formation (over 21ºC), No potato formation (over 29ºC)

Table 3. High temperature injury of crops (Yamazaki, 1985).

2.2.1 Effect of high temperatures on crop production in different areas

The increase in temperatures resulting from higher concentrations of CO_2 in the atmosphere may inhibit or promote crop growth. Naturally, such climatic changes will directly affect agricultural production. It is anticipated that for moderate global average temperature increases (1–3°C) there will be an overall increase in global food production. Additional temperature increases, however, would result in an overall decrease in food (IPCC, 2007). In low-latitude regions such as seasonally dry tropical areas, even moderate temperature increases (1–2°C) are likely to negatively affect major cereal crops, increasing the risk of famine. By the mid-21st century, crop yields in East and Southeast Asia may increase by up to 20%, while those in central and South Asia may decrease by up to 30% if the direct positive physiological effects of CO_2 are taken into account. Western New Zealand is likely to receive more rain, but large areas of mainland Australia and eastern New Zealand are likely to have less soil moisture. Therefore, the increased drought and frequency of fires could decrease crop production. In North America, it is predicted that there will be climate-related yield increases of 5–20% over the first decades of the century, with overall positive effects of climate persisting through much or all of the 21st century. However, crops that are currently growing in areas that are close to their climate thresholds (e.g., wine grapes in California) are likely to show decreases in yield and/or quality in response to even modest increases in temperature (Hayhoe et al., 2004; White et al., 2006). In drier areas of Latin America, climate change is likely to lead to salinization and desertification of agricultural lands, and therefore, food production and security will fluctuate. In some African countries, climate change could exacerbate erosion, and decreases in yields from rain-fed agriculture of up to 50% during the period from 2000 to 2020 (Agoumi, 2003).

2.2.2 Effect of high temperatures on crop growth

Rice

In rice, seed abortion occurs when plants are subjected to temperatures above 35°C. When the average temperature exceeds 26–27°C at 20 days after ear emergence, grain filling and grain quality are decreased, and there are more immature grains.

Wheat

The number of wheat tillers decreases in response to high temperatures, especially high night-time temperatures. In such conditions, shoot elongation is promoted but there are more immature grains and decreased yields because of dark respiration. Moreover, unusually early panicle initiation caused by warm winters can increase the risk of frost damage.

Soybean

The growth of soybean decreases above 38°C, but soybean is relatively heat-tolerant. However, pollen viability was lower at day/night temperature conditions of 37/27°C than at 27/27°C, and the rate of pod setting at 32/27°C was lower than that at 27/27°C (Kitano et al., 2006).

Tomato

At high temperatures, seedlings grow faster and the differentiation and development of flowers is also promoted. However, the rate of flower set decreases and flowers are of poor quality. High temperatures during flowering induce flower abscission, malformed flowers, and pollen sterility in tomato plants. High temperatures also result in poor flowering, poor fruit quality, and color disorders.

Cucumber

High temperatures result in faster seedling growth. However, the development of pistillate and bisexual flowers is suppressed, the node order of the flowers increases, and the number of flowers decreases. High temperatures inhibit flower differentiation and development, and result in smaller ovaries in pistillate and bisexual flowers.

Lettuce

Since lettuce is a cool-temperature crop, it is likely to be adversely affected by higher temperatures. Higher temperatures induce floral differentiation and flower stalk development in lettuce plants, both of which decrease yield and quality of the crop.

Carrot

Carrot is another cool-temperature crop, and so higher temperatures and drier conditions inhibit seed germination and plant growth. Moreover, high temperatures and wet conditions result in shorter, thicker roots. The major risk for carrots, however, is the predicted increase in disease damage in warmer, wet conditions.

Potato

The night-time temperature is important for formation of potato tubers. The optimum temperatures are 20°C days and 10–14°C nights, but almost no tubers form if night-time temperatures exceed 20°C. In warm, wet conditions, the stolon-formation period is shorter, the tubers are smaller, and the tuber quality is poor (e.g. some have hollow hearts).

Strawberry

Floral differentiation of strawberry is strongly affected by temperature and photoperiod. At low temperatures (5–10°C), flower buds form regardless of the photoperiod. At 11–15°C, flower buds can form, but only with increased light intensity under long-day conditions. At 16–26°C, flower buds form under a short-day photoperiod (less than 12-h days), and no flower buds form above 27°C. Therefore, high temperatures will delay floral formation and result in small fruits.

2.2.3 Weeds, harmful insects, and diseases

To achieve high yields, crops must be protected from pests, diseases, and weeds. Of the total cropping area worldwide, crop yield is decreased by 10–20% by weeds (Mirrabelli et al., 2005). Many C_4 weeds are found in arable C_3 crops and many C_3 weeds in arable C_4 crops. Therefore, under high temperatures and increased atmospheric CO_2 concentrations, weed damage to arable C_4 crops in tropical and subtropical semiarid areas is predicted to increase. It is likely that global warming will result in pests and diseases that are currently found in low-latitude regions spreading to high-latitude regions. Bacteria and fungi are the main causal agents of plant diseases, and their optimal growth temperatures are approximately 25°C and above 30°C, respectively. Temperature also affects the growth of insects, with higher temperatures increasing their growth rate. Therefore, continued warming is expected to increase damage to crops from bacteria, fungi, and insects.

3. Water shortages, desertification, and tropical cyclones

As global warming progress, there will be increased evaporation from the earth's surface and from plants. Even a 1°C temperature increase would increase the amount of evaporation from the earth. As well, increased temperatures result in more concentrated, heavy rainfall, and crops show decreased rainfall use efficiency in such circumstances. Snowfall, which results in stored water resources, also decreases with higher temperatures, and snow melts more rapidly. Together, these factors could combine to increase drought in the major agricultural regions—the mid-latitude continents. This could significantly restrict the world's food supply.

Desertification of dry areas is very likely to result from global warming. In dry areas, water moves from subsurface to surface layers of the soil. Therefore, when capillary water reaches the ground or irrigation water evaporates, the soluble salts that dissolved into the water in the lower layers are concentrated in the surface soil layer. As a result, salt accumulates at the soil surface, where it negatively affects or prevents plant growth. In dry regions, more water will evaporate as temperatures increase, turning these areas into deserts. Desertification decreases the amount of vegetation, reducing CO_2 absorption by plants, and further progressing global warming. The area of the world's deserts is expanding by 60,000 km^2 each year, and the desertification of humid and semi-arid areas and the dry sub-humid areas used to cultivate wheat and other grains could cause a serious food crisis.

Strong tropical storms, hurricanes, typhoons, and cyclones severely damage farmland. The numerous tropical storms in recent years are thought to be a result of global warming. Theoretically, the increase in the number of strong tropical storms is because of increased evaporation—the energy source for tropical storms—due to the rise in the temperature of the ocean's surface (Emanuel, 1987). Walsh (2004) indicated that the tropical cyclone intensity will increase by 5–10% around 2050, along with increased peak rainfall rates of approximately 25%. More recent climate model predictions are that the number of cyclones will decrease by approximately 30% under global warming, but their duration will be longer (Oouchi et al., 2005). Therefore, low-lying areas could be at high risk because of longer tropical storms and increased sea levels.

4. Countermeasures

Some strategies to ameliorate the effects of global warming on food production include the development and use of heat-tolerant varieties, appropriate nutrient and water management, coordination of growing periods, and control of pests and diseases. In particular, pest/disease control and the use of heat-tolerant crops are thought to be the most promising approaches. Soybean is sensitive to drought, and so adequate irrigation must be provided when its evapotranspiration rate increases in response to higher temperatures. Although wheat is relatively drought-tolerant, water shortages in dry areas are a concern, so efficient irrigation techniques, e.g. drip irrigation, should be used. The male sterility that results from high-temperature injury decreases the yields of wheat and maize, but treatment with the plant hormone auxin can restore fertility (Fig. 4; Sakata et al., 2010).

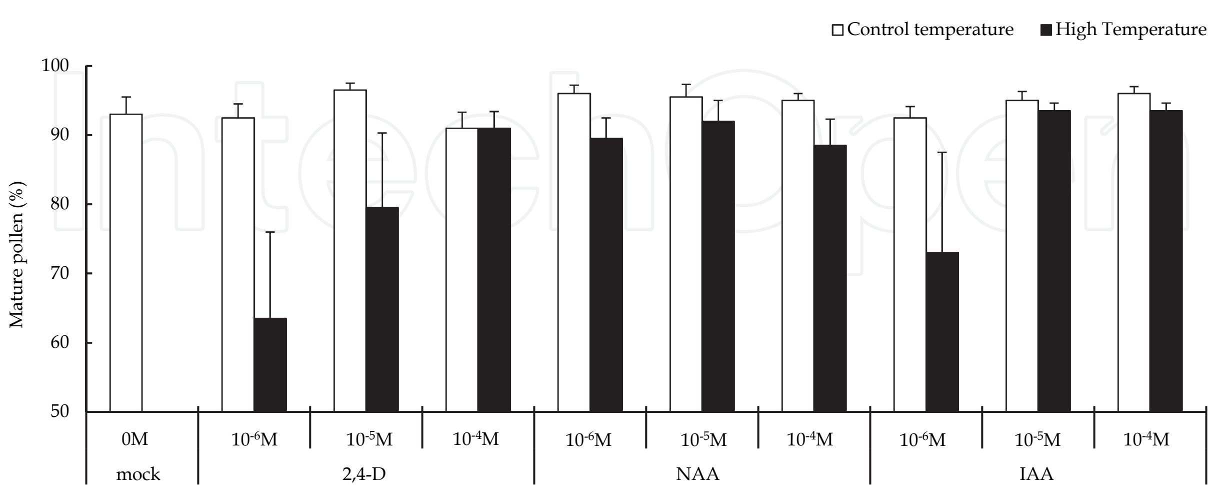

Fig. 4. Effects of exogenous auxin on high temperature injury of pollen developments in barley. A population of mature pollen grains were recovered from anthers after all auxin applications testeed. (Sakata et al., 2010).

For leafy crops, mulching and shading are useful techniques to prevent increases in the soil temperature. For fruit crops, useful techniques include the use of various materials to shade and heat-shield trees, and coordination of the growing period. A night-chilling treatment is a useful countermeasure to induce floral differentiation of strawberry. For crops in protected cultivation, the combination of heat pumps, evaporative cooling, air ventilation, and shading can achieve optimum growth conditions.

Rootstock	Desination	NaCl (mM)			
		0		50	
Moneymaker	M/M	201.2 ± 12.4	a	128.4 ± 10.1	b
Radja	M/R	242.9 ± 16.8	a	145.8 ± 24.3	b
Pera	M/P	238.2 ± 34.1	a	202.4 ± 24.4	a

Table 4. Shoot fresh weight (g plant−1) of self-grafted Moneymaker plants and Moneymaker grafted onto two rootstocks (Radja and Pera) after 35 days of salt treatment (Martinez-Rodriguez et al., 2008).

Results as means±S.E. (n = 6). Means within each column followed by different letters are significantly different according to the LSD test (P≤0.05).

4.1 Parthenocarpy

Fruit develops from the ovary, which itself develops in response to plant hormones that are produced by seeds formed after fertilization. Fertilization is the fusion of pollen (formed in the anther) and the ovule (formed in the ovary). However, because pollen is temperature-sensitive, high temperatures during pollen formation induce male sterility. If global warming proceeds at the current rate, fruit production could be affected in fruit and vegetables that require fertilization. Parthenocarpy is the natural or artificially induced production of fruit without fertilization of ovules, so this is a promising strategy for fruit production under global warming. Natural parthenocarpy involves using varieties that have parthenocarpic genes, while artificial parthenocarpy is induced by hormone treatment. Examples of parthenocarpy include the production of seedless grapes using GA treatment, and tomato, eggplant, and cucumber production using auxin treatment. Crops in which natural parthenocarpy is exploited include oranges, pineapple, banana, tomato, eggplant, and cucumber. In general, parthenocarpic fruit trees are propagated by vegetative propagation and parthenocarpic vegetables are propagated by F_1 seeds. Therefore, the use of parthenocarpic vegetables is limited because few seeds are formed in these vegetables. Recently, a method was reported to enhance seed production in parthenocarpic tomato fruits (Fig. 5; Johkan et al., 2010). This method can be applied to other crops, and therefore, it may allow more extensive use of parthenocarpic fruits in the future.

4.2 Grafting

Grafting is the vegetative propagation of fruit trees, but in Japan, it has also been used to avoid injury by continuous cropping of vegetables and soil pests and diseases. Vegetable fruits that can be grafted include cucurbits such as melons, watermelon, and cucumber, and

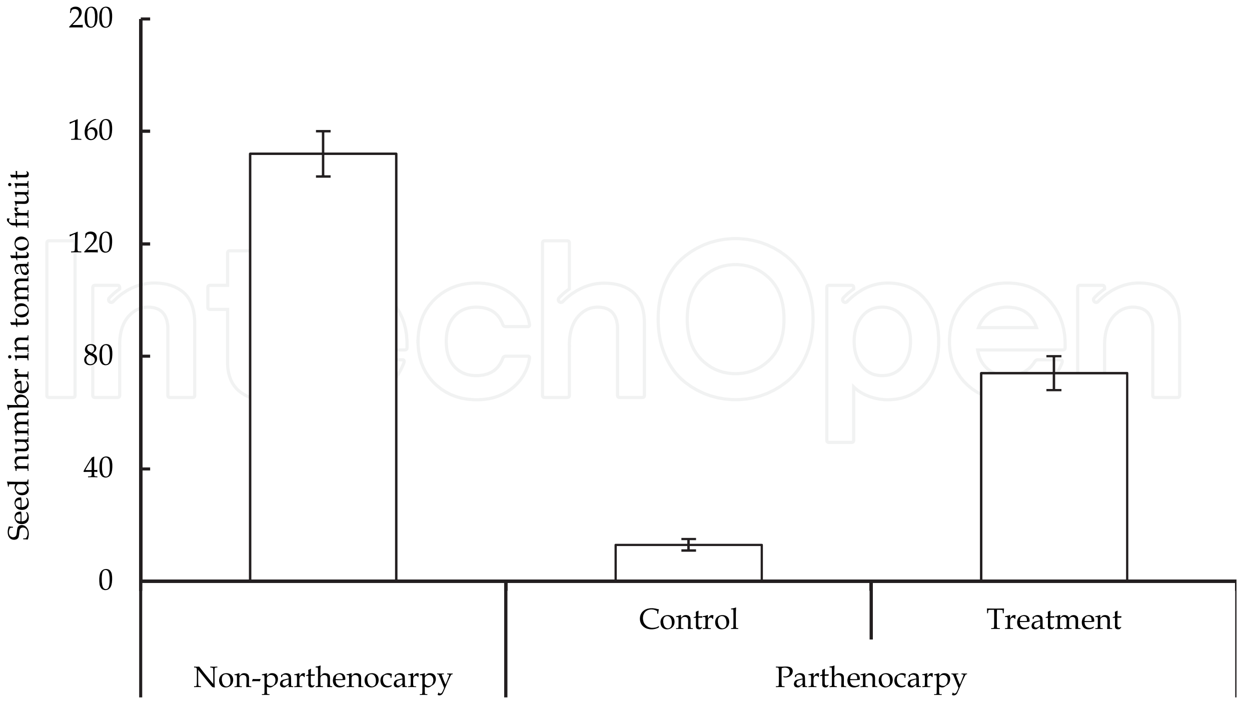

Fig. 5. Increase of seed formation in parthenocarpic tomato fruit (Johkan et al., 2010).

solanaceous species such as tomato and eggplant. Grafting can give the characteristics of the rootstock to the scion. Some rootstocks will be more tolerant to adverse environmental conditions. In particular, grafting scions to rootstock with high drought- or heat-tolerance can increase growth and yield under high temperatures (Fig. 6, Rivero et al., 2003). In addition, crops that are not salt tolerant can be cultivated in saline areas if grafted onto salt-tolerant rootstock. As mentioned above, grafting is an effective countermeasure for crop production without the need to breed lines that are tolerant to heat or drought.

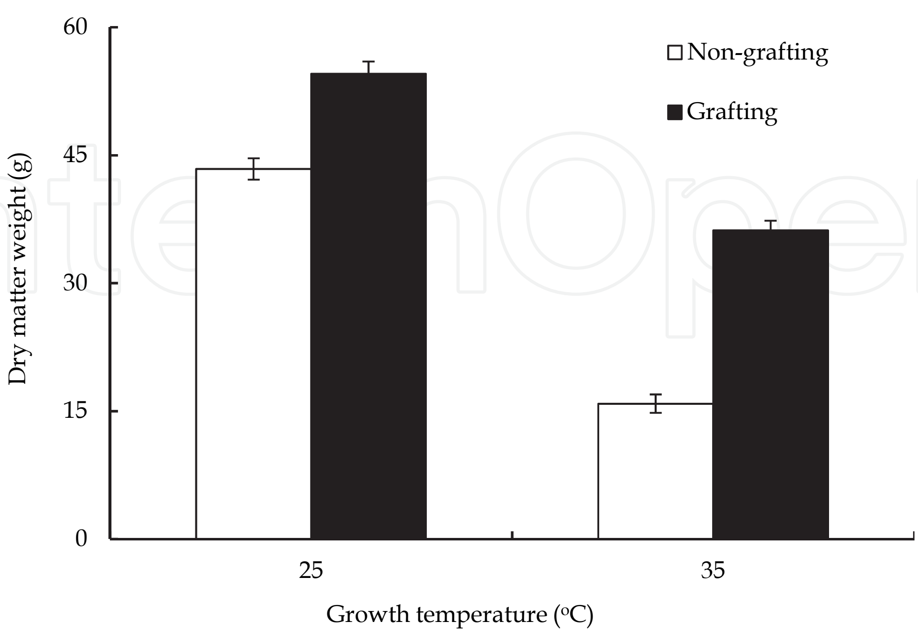

Fig. 6. Effect of grafting on growth of tomato shoots at high temperature (Rivero et al., 2003).

4.3 Vegetative propagation

The use heat-tolerant cultivars are an effective countermeasure against global warming. Breeding of heat-tolerant varieties is required if there are no suitable varieties for the local area. However, propagation by seeds requires genetic fixation, which is a lengthy process. In contrast, vegetative propagation does not require genetic fixation, so it can be used for rapid release of pathogen-resistant or desirable cultivars. One disadvantage of vegetative propagation is that it is less efficient than seed propagation. However, an *in vivo* mass propagation method was recently reported for tomato. This method markedly increased the multiplication rate (Johkan et al., 2008), and could be applied to other plants. As mentioned above, if immediate action is required to ameliorate the effects of global warming, vegetative propagation may be one effective method.

5. Conclusion

The effects of global warming on food production are complex, and are a combination of increased CO_2 concentrations in the atmosphere, higher temperatures, fluctuations in rainfall and solar radiation, and pests and diseases. The 'fertilizing effect' of elevated CO_2 concentrations on crop yields will decline slightly because of the negative effects of rising temperatures. Particularly in developing areas with undeveloped agricultural technologies, there is a high risk that a hotter, drier climate will negatively affect crop production. In mid- and high-latitude regions, even a moderate increase in the global average temperature (1–3°C) could increase food production, but additional temperature increases would cause an overall decline in food production. In low-latitude regions, especially seasonally dry semitropical areas, temperature increases of only 1 or 2°C are likely to negatively affect cereal production because of drought. Although the effect of global warming on food production will vary among regions and crop types, it is anticipated global food production will decrease, and the North-South gap in food production will become greater than it is at present. Therefore, it is important to reexamine existing varieties, to introduce new varieties with increased tolerance to high temperatures and pests/diseases, and to improve methods of pest and disease control.

Parthenocarpy, grafting, and vegetative propagation should also be considered as useful countermeasures against global warming. However, temperature strongly affects crop production, and the extent to which countermeasures can ameliorate the effects of global warming are limited. Global warming is a common problem for all people living on earth. There is no doubt that to address the issue of global warming together is the most effective strategy to guarantee stable crop production.

6. References

Agoumi, A. (2003). Vulnerability of North African countries to climatic changes: adaptation and implementation strategies for climatic change. In: *Developing Perspectives on Climate Change, Issues and Analysis from Developing Countries and Countries with Economies in Transition*, Climate Change Knowledge Network, (May, 2003), Available from http://www.cckn.net//pdf/north_africa.pdf.

Amthor, J. F. (2001). Effects of atmospheric CO_2 concentration on wheat yield: review of results from experiments using various approaches to control CO_2 concentration.

Field Crops Rearch, Vol.73, No.1, (October, 2001), pp. 1-34, ISSN 0378-4290

Aoki, M. & Yabuki, K. (1977). Studies on the carbon dioxide enrichment for plant growth. VII. Changes in dry matter, production and photosynthetic rates of cucumber during carbon dioxide enrichment. *Agricultural Meteorology*, Vol,18, No.6, (December, 1977), pp. 475-485, ISSN 0002-1571

Cock, J. H. & Yoshida, S. (1973). Changing sink and source relations in rice (*Oryza sativa* L.) using carbon dioxide enrichment in the field. *Soil Science of Plant Nutriton* Vol.19, No.3, (September, 1973), pp. 229-234, ISSN 0038-0768

Emanuel, K. A. (1987). The dependence of hurricane intensity. *Nature*, Vol. 326 No.6112, (April, 1987), pp. 483-485, ISSN. 0028-0836

Hayhoe, K.; Cayan, D.; Field, C.; Frumhoff, P.; Maurer, E.; Miller, N.; Moser, S.; Schneider, S.; Cahill, K.; Cleland, E.; Dale, L.; Drapek, R.; Hanemann, R. M.; Kalkstein, L.; Lenihan, J.; Lunch, C.; Neilson, R.; Sheridan S. & Verville J. (2004) Emissions pathways, climate change, and impacts on California. *Proceedings of the National Academy of Sciences*, Vol.101, No.34, (August, 2004), pp. 12422-12427, ISSN 0027-8424

Imai, K.; Coleman, D. F. & Yanagisawa, T. (1985). Increase in atmospheric partial pressure of carbon dioxide and growth and yield of rice (*Oryza sativa* L.). Japanese Journal of Crop Science, Vol.54, No.4, (December, 1985), pp. 413-418, ISSN 0011-1848 (In Japanese with English abstract)

Intergovernmental Panel on Climate Change (IPCC). (2007b). In: *Climate Change 2007: Impacts, Adaptation and Vulnerability*, 29.08.2007, Available from http://www.ipcc-wg2.org/

Johkan, M.; Mori, G.; Mitsukuri, K.; Mishiba, K.; Morikawa T. & Oda, M. (2008). In vivo shoot regeneration promoted by shading the cut surfaces of the stem in tomato plants. *HortScience*, Vol.43, No.1 (February, 2008), pp. 220-222, ISSN 0018-5345

Johkan, M.; Chiba, T.; Mitsukuri, K.; Yamasaki, S.; Tanaka, H.; Mishiba, K.; Morikawa, T.; Oda, M.; Yamamoto, C. & Ohkawa. H. (2010). Seed Production Enhanced by Antiauxin in the pat-2 Parthenocarpic Tomato Mutant. *Journal of the American Society for Horticultural Science*, No.135, Vol.1 (January, 2010), pp. 3-8, ISSN 003-1062

Kitano, M.; Saitoh, K. & Kuroda, T. (2006). Effect of high temperature on flowering and pod set in soybean. *Scientific Reports of the Faculty of Agriculture Okayama University*, No.95, Vol.1, (February, 2006), pp. 49-55. ISSN 0474-0254

Makino, A. (1994). Biochemistry of C_3-photosynthesis in High CO_2. *Journal of Plant Research*, Vol.107, No.1, (March,1994), pp. 79-84. ISSN 0918-9440

Martinez-Rodriguez, M. M.; Estan, M. T.; Moyano, E.; Garcia-Abellan, J. O.; Flores, F. B.; Campos, J. F.; Al-Azzawi, M, J,; Flowers, T.j. & Bolarin. M. C. (2008). The effectiveness of grafting to improve salt tolerance in tomato when an 'excluder' genotype is used as scion. *Environmental an Experimental Botany*, Vol.63, No.1-3, (May, 2008), pp. 392-401, ISSN 0098-8472

Millabelli, C.; Colla, G.; Fiorillo, A.; Cardarelli, M.; Rouphael, Y. & Paolini, R. (2005). The effect of mechanical weed control technique and irrigation method on yield, tuber quality and weed suppression in organic potato. Acta Horticulturae (ISHS), No.684, Vol.1, (October ,2005), pp. 127-134, ISSN 0567-7572

Nakano, H.; Makino, A. & Mae, T. (1997). The Effect of Elevated Partial Pressures of CO_2 on the Relationship between Photosynthetic Capacity and N Content in Rice Leaves. *Plant Physiology*, Vol.115, No.1 (February,1997), pp. 191-198, ISSN 0032-0889

Oouchi, K.; Yoshimura, J.; Yoshimura, H.; Mizuta, R.; Kusunoki, S. & Noda, A. (2006). Tropical cyclone climatology in global-warming climate as simulated in a 20 th km-mesh global atmospheric model. *Journal of the Meteorological Society of Japan*, Vol.84, No.2, (April, 2006), pp. 259-276. ISSN 0026-1165

Prasad, P. V. V.; Boote, K. J.; Allen Jr., L. H.; Sheehy, J. E. & Thomas, J. M. G. (2006). Speicies, ecotype and cultivar differeces in spikelet fertility and harvest index of rice in response to high temperature stress. Field Crop Research, Vol.95 No.2-3, (February, 2006), pp. 398-411, ISSN 0378-4290

Rivero, R. M.; Ruis, J. M.; Sanchez, E. & Romero, L. (2003). Does grafting provide tomato plants an advantage against H2O2 production under conditions of thermal shock? *Physiologya Plantarum*, Vol.117, No.1, (January, 2003), pp. 44-50, ISSN 0031-9317

Rogers, H. H. (1983). Responses of selected plant species to elevated carbon dioxide in the field. *Journal of Environnemtal Quality*, Vol.12, No.4 , (December, 1983), pp. 569-574. ISSN 0047-2425

Rogers, H. H. and Runion, G. B. (1994). Plant responses to atmospheric CO2 enrichment with emphasis on roots and the rhizosphere. *Environ. Pollu.* Vol.83, No.1-2, (October,1994), pp. 155-189. ISSN 0269-7491

Sage, R.F.; Sharkey, T. D. & Seemann, J. R. (1989). The acclimation of photosynthesis to elevated CO_2 in five C_3 species. *Plant Physiology*, Vol.89, No.2, (February, 1989), pp. 590-596, ISSN 0032-0889

Saitoh, H. (Ed.). (2008). *Ecological and physiology of vegetable*, Nousangyoson Bunka Kyoukai, ISBN 978-4-540-08114-9, Tokyo, Japan (In Japanese)

Sakata, T.; Oshino, T.; Miura, S.; Tomabechi, M.; Tsunaga, Y.; Higashitani, N.; Miyazawa, Y.; Takahashi, H.; Watanabe, M. & Higashitani, A. (2010). Auxins reverse plant male sterility caused by high temperatures. *Proceedings of the National Academy of Sciences*, Vol.107, No.19, (May, 2010), pp. 8569-8574, ISSN 0027-8424

Usuda, H. & Shimogawara, K. (1998). The Effects of Increased Atmospheric Carbon Dioxide on Growth, Carbohydrates, and Photosynthesis in Radish, Raphanus sativus. *Plant Cell Physiology*, Vol.39, No.1, (January, 1998), pp. 1-7, ISSN 0032-0781

Walsh, K. (2004). Tropical cyclones and climate change: unresolved issues. *Climate Research* Vol.27, No.1, (January, 2004), pp. 77-83, ISSN 0936-577X

White, M. A.; Diffenbaugh, N. S.; Jones, G. V.; Pal, J. S. & Giorgi, F. (2006). Extreme heat reduces and shifts United States premium wine production in the 21st century.

Proceedings of the National Academy of Sciences, Vol.103, No.30, (July, 2006), pp. 11217-11222, ISSN 0027-8424

Yamazaki, K. (1985). Growth and physiology of vegetable, In *Vegetable Horticultural Dictionary*, S. Shimizu, (Ed.) pp. 245-252, Yokendo, Tokyo, Japan (In Japanese)

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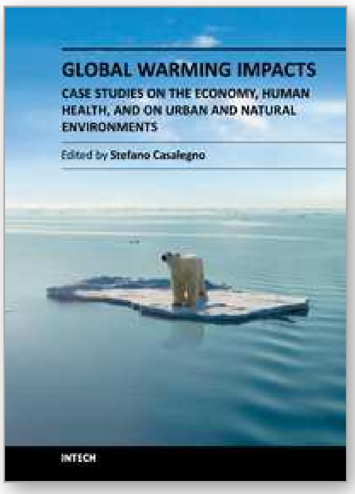

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This book addresses the theme of the impacts of global warming on different specific fields, ranging from the regional and global economy, to agriculture, human health, urban areas, land vegetation, marine areas and mangroves. Despite the volume of scientific work that has been undertaken in relation to each of each of these issues, the study of the impacts of global warming upon them is a relatively recent and unexplored topic. The chapters of this book offer a broad overview of potential applications of global warming science. As this science continues to evolve, confirm and reject study hypotheses, it is hoped that this book will stimulate further developments in relation to the impacts of changes in the global climate.

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