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Shon, Tae-Kwon
Laboratory of Crop Science, Faculty of Agriculture, Kyushu University

Haryanto, Totok Agung Dwi
Laboratory of Crop Science, Faculty of Agriculture, Kyushu University

Yoshida, Tomohiko
Laboratory of Crop Science, Faculty of Agriculture, Kyushu University

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Dry Matter Production and Utilization of Solar Energy in One Year Old *Bupleurum falcatum*

Tae-Kwon Shon, Totok Agung Dwi Haryanto and Tomohiko Yoshida

Laboratory of Crop Science, Faculty of Agriculture,
Kyushu University, Fukuoka 812-81, Japan
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Dry matter production and solar radiation utilization were studied for *Bupleurum falcatum*, originated from Jeongseon, Korea and Kumamoto, Japan. The root growth of the plants from Kumamoto was more vigorous than that of the plants from Jeongseon. The former was also higher in dry matter production of aerial part and in leaf area. The utilization of solar energy in the stage around 150 days after sowing were 2.42% and 1.48% in Kumamoto and Jeongseon, respectively. The values of crop growth rate, and net assimilate rate of Kumamoto were higher than Jeongseon during whole growth except net assimilate rate during July 31 to August 15. The growth and yield of one year old plants under field condition in Jeongseon were inferior, but superior in the 1000 seed weight. Generally, the plants from Kumamoto showed higher mean values of the parameters measured than those from Jeongseon. This was interpreted to suggest the difference between the plants of geographical origin and the potential crop productivity in *B. falcatum*.

INTRODUCTION

Generally, plant growth depends on photosynthesis, respiration and distribution of assimilates into various plant parts in relation to illumination, temperature and age of plants. However, there are only a few information about the study of growth, development, dry matter (DM) production and solar energy utilization efficiency (Eu) in B. *fatcatum* (Horikoshi *et al., 1976;* Shimokawa *et al.*, 1980). Shimokawa *et al.* (1980) reported that the root growth of the plants from Shizuoka and from Kagawa were more vigorous than that of the plants from Yamaguchi. For comparing two-year B. *falcatum* collected from six different habitats, the plants from Hokkaido showed inferior in the growth of top, but superior in the yield of root (Horikoshi *et al.,* 1976).

Recently much information about the DM production and Eu from many plants in different localities and growth conditions have been obtained (Aboagye et al., 1995; Kokubun and Watanabe, 1981; Sinclair *et al., 1992;* Shibles and Weber, 1966; Yoshida, 1979). On the basis of these data, statistical analysis have been made on the relationship between climatic factors and the yield or productivity of plants. The estimation of the Eu and DM production can be used to improve the production of many plants. Murata (1981) presented an analysis of the relationship between crop growth rate (CGR) and leaf photosynthetic activity and Eu among various crop species and concluded that Eu corresponding to the max CGR was shown to be higher in the C_4 species than in the C_3 species. Further, a very close correlation was found between photosynthetic activity and the corrected Eu. Ensuing experiments reported about Eu within crop species, important differences among species were also found. Yamamoto et al. (1996) summarized a number of field experiments as well as additional data of their own, and reported values of Eu of 1.09% for barley, 1.15-1.94% for rice and 0.92% for soybean. From a theoretical derivation of Eu, Sinclair and Horie (1989) showed that the differences in radiation-use efficiency (RUE) among species should be expected. In addition, they showed RUE would vary within a species, depending on the light-saturated rate of leaf photosynthesis. Shibles and Weber (1965) reported that DM production in equidistantly-spaced soybeans was a linear function of solar radiation interception. Sequentially, as growth progressed, increasing rate of DM production depended on increasing leaf area development. The efficiency of utilization of intercepted energy differed between years for the mean among planting patterns (Shibles and Weber, 1966). Thus, the relevance of leaf area and occupancy of interplant spaces resulted in increasing percent solar radiation interception which, in turn, resulted in an increasing rate of DM production.

B. falcatum are usually produced under row culture, and also have many variation of geographical origins or plant characters (Kim *et al*., 1995; Minami et al., 1995; Shimokawa *et* al., 1980; Tam *et al.*, 1987). It seemed reasonable to hypothesize the differences of growth characters among geographical origins.

The objective of this study is to assess the Eu and DM production and the variation between plants originated from different habitats in *B. falcatum* .

MATERIALS AND METHODS

B. falcatum, originated from Jeongseon, Korea and Kumamoto, Japan, were used for materials. These were cultivated under field conditions at the Experimental Farm, Faculty of Agriculture, Kyushu University, in 1995. Seeds were sown by hand on April 5 and thinned to the spacing of 30 *x* 20 cm between and within rows on May 20. Fertilizer in the ratio 18:18: 18 kg of N, P_2O_5, and K_2O per 10a were applied just before sowing.

Samples for leaf area index (LAI), DM production, CGR, relative growth rate (RGR), and net assimilation rate (NAR) determination were taken at 7 stages of development every 2 weeks from 90 days after sowing. These values were determined by sampling the area of 0.3 m^2 *x* 2. Sample plants were divided into three parts, leaf, stem, and root. Each of them was dried at 70 ˚C for a day and weighed. On the basis of DM weight and LA obtained, three production parameters, CGR, RGR, and NAR, were calculated from the equations (1) to (3) shown below.

$$\mathrm{CGR}=\frac{dw}{dt}=\frac{W_2-W_1}{t_2-t_1} \quad \text{-------------------- (1)}$$

$$\mathrm{PGR}=\frac{1}{W}\cdot\frac{dw}{dt}=\frac{\log W_2-\log W_1}{t_2-t_1} \quad \text{-------------- (2)}$$

$$\mathrm{NAR}=\frac{1}{A}\cdot\frac{dw}{dt}=\frac{\log A_2-\log A_1}{A_2-A_1}\cdot\frac{W_2-W_1}{t_2-t_1} \quad \text{------------ (3)}$$

where W is DM weight per plant, t is sampling day and A is leaf area per plant.

Eu was expressed by the ratio of the total combustion energy contained in the dry matter, AW, produced on a unit field area during a definite period to the total short wave solar radiation, S, incident on the plants during the same period, as shown by the following equation:

$$Eu = \frac{AW\ (g/m^2) \times 16.8\ (kJ/g)}{S\ (kJ/m^2)} \times 100 \text{ - - - - - - - - - - - - - - - - } (4)$$

Where 16.8 kJ/g (= 4 kcal/g) stands for heat of combustion per gram of DM. Values of temperature, precipitation and S were obtained from Fukuoka District Meteorological Observatory.

RESULTS

The climatic conditions showed similarity in the mean of air temperature, but were quite different in the mean of precipitation, i.e., there was higher precipitation in July, comparing to normal (Fig. 1). Solar radiation was more higher than normal (Fig. 2).

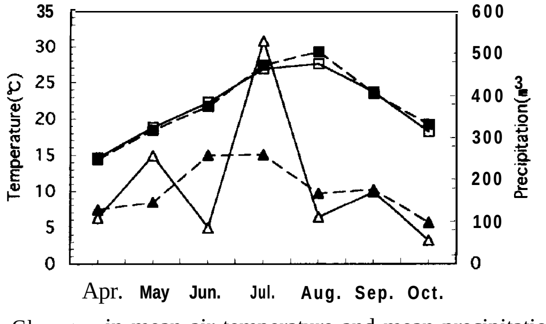

Fig. 1. Changes in mean air temperature and mean precipitation in a month during from April to October 1995 in Fukuoka, Japan.
□; Temperature: △; Precipitation; --■--,--▲--; Normals.

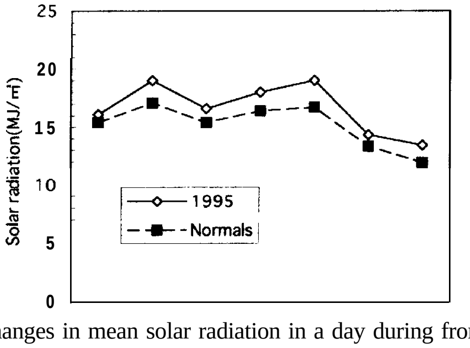

Fig. 2. Changes in mean solar radiation in a day during from April to October 1995 in Fukuoka, Japan.

1. Dry matter production and leaf area

Changes in DM production of aerial part and root increase between stages are shown in Fig. 3.

Higher DM and LA (Fig. 4) were produced in Kumamoto as compared to Jeongseon. Aerial part weight, root weight and LA increased rapidly during vegetative growth stage and late flowering stage. Approximately 165 days after sowing, September 12, DM of aerial part was near to the maximum value (Fig. 3). The highest DM was achieved in around 165 days after sowing as 374.5 g/m^2 (Kumamoto) and 265.6 g/m^2 (Jeongseon). DM accumulation in aerial part and root showed similar response in each stage for the plants from both origins. Maximum LAI was 1.34 and 1.06 at 135 days after sowing in Jeongseon and Kumamoto, respectively. The increasing of LA continued after flowering stage.

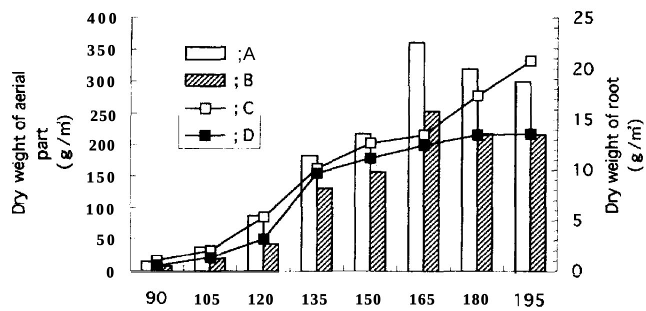

Fig. 3. Dry matter production of aerial part and root in one year old *Bupleurum falcatum*.
A: Dry weight of aerial part in Kumamoto, B: Dry weight of aerial part in Jeongseon, C: Dry weight of root in Kumamoto, D: Dry weight of root in Jengseon.

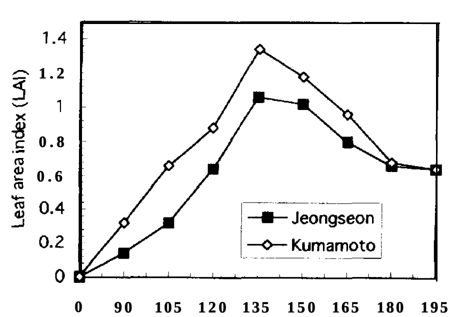

Fig. 4. Changes in leaf area index (LAI) in one year old *Bupleurum falcatum*.

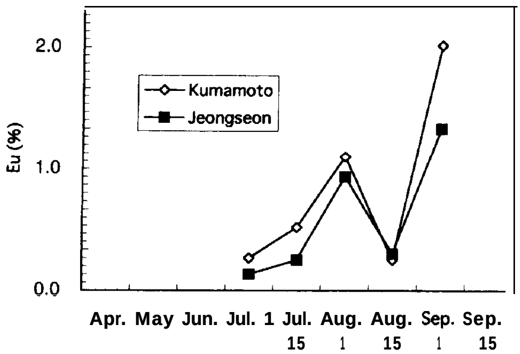

Fig. 5. Efficiency of solar energy utilization (Eu) in one year old *Bupleurum falcatum*.

2. Growth parameters and Eu

For CGR, during the growth period, the high values were observed at the vegetative growth stage and late flowering stage. In the highest CGR value, in the late flowering stage, Kumamoto showed higher value than that of Jeongseon as 21.04 and 12.83, respectively. It had rapidly increased in vegetative growth stage and late flowering stage (July 31-Rug. 15 and Aug. 29-Sep12), but RGR had increased in both of Kumamoto and Jeongseon. NAR values were 12.83 (Jeongseon) and 21.04 (Kumamoto) in this time. Eu were 1.23% (Kumamoto) and 1.02% (Jeongseon) in vegetative growth stage and the highest value was observed in the late flowering stage as 2.42% (Kumamoto) and 1.48% (Jeongseon) (Fig. 5). All values of CGR, NAR, and Eu were higher in Kumamoto than those of Jeongseon except the value of NAR of July 17-31.

3. **Growth characters and Yield**

Table 1 represented yield and various characteristics on one year old B. *alcatum* of different geographical origins. From sowing to germination, it took about 1 month. Plants flowered 113-l 17 days after sowing. Germinating and flowering time of Kumamoto were few days later than those of Jeongseon. The average of plant height was 70.9 cm for Jeongseon and 80.1 cm for Kumamoto. The root diameter of Kumamoto was much larger than that of Jeongseon, while, it showed opposite result in 1000 seed weight. Root yield of Kumamoto was 36.3 g/m^2 and higher than Jeongseon as 28.4 g/m^2.

Table 1. Yield and various charecteristics in one year old *Bupleurum falcatum* of different geographical origins.

Geographical origin	sowing date	Germinating time	Flowering time	Plant height (cm)	Root diameter (mm)	1000 seed weight (g)	Yield of root (g/m^2)
Jeongseon	Apr. 5	May 5	Jul.28	70.9	81.1	1.79	28.4
Kumamoto	Apr.5	May 8	Aug. 1	80.1	87.4	1.65	36.7

Table 2. Growth analysis of one year old *Bupleurum falcatum*.

		Jul. 3-17	Jul. 17-31	Jul. 31-Aug.15	Aug. 15-29	Aug. 29-Sep.12	Sep.12-28	Sep.28-Oct.14
Jeongseon	CGR	1.73	3.64	11.70	6.31	12.83	–	–
	RGR	0.07	0.06	0.07	0.02	0.03	–	–
	NAR	7.95	7.87	14.00	6.06	14.15	–	–
Kumamoto								
	CGR	3.48	7.62	14.01	4.43	21.04	–	–
	RGR	0.07	0.06	0.05	0.01	0.04	–	–
	NAR	7.40	9.96	12.80	3.52	19.71	–	–

Note: Values were estimated by harvesting $0.3m^2 \times 2$. CGR= crop growth rate (g/m^2/day), RGR = relative growth rate (g/g/day), NAR = net assimilation rate (g/m^2/day).

DISCUSSION

DM production is characterized by a similar response to LAI. A comparison of both showed that DM production was a similar function of LAI (Fig. 3 and 4). It revealed that the relationship between DM production and LAI was linear. Broughum (1956) found that both percent solar radiation interception and rate of DM production increased with LA development and approached a maximum. The results obtained from our study showed that the curve of growth showed three distinct phases. For approximately 2 and a half months, the growth rate increased slowly, then, for 2 month late the increase was rapid, and thereafter it declined. Maximum DM production continued until late flowering stage. Eu and rate of DM production increased with increasing LA development until LA reached a maximum. It suggested that Eu was related to LA and DM production and the direct correspondence between rate of DM production and solar energy utilization had important implications in addition to the spacing and arrangement of LA and plants.

Isoda et al. (1994) reported that the cultivar with sparse leaf area in the upper layers of the canopy or with smaller leaflets intercepted larger amount of radiation in soybean. In peanut, the small and dense leaf cultivar showed lower intercepted radiation per unit leaf area index (interception efficiency) (Aboagye *et al.*,1994). But, Maeda (1993) reported that the erect type and less branching habits of subspecies *fastigita* had been introduced into ssp. *hypogaea* resulting in higher yields. Aboagye *et al.* (1995) suggested that high radiation interception efficiency through, particularly, the reduction of self and/or mutual shading would increase DM production in peanut. The maximum LAI in this experiment was 1.34-1.06 and not so high. Eu values were very low compared to various plants in Murata (1981). In our experiment, there was positive relation between NAR vs. LAI, DM production vs. LAI, Eu vs. LAI, and Eu vs. DM production. The plants of Kumamoto had relatively high LAI, NAR and CGR value than those of Jeongseon. It was also higher in all of growth characteristics, plant height, root diameter, and yield, except 1000 seed weight. Eu showed higher value after flowering stage. All these facts suggest that the larger leaf and/or more LA plant in earlier growth stages may confer greater Eu, bigger DM production and higher yield in the case of *B. falcatum*. To progress the genetical and agronomical improvements of these plants, more information is required on growth and production physiology in the field.

The roots of B. *falcatum,* which have saikosaponin a, c, and d as main ingredient, are wildly used for crude herbal drugs. A report about saikosaponin contents in roots is in preparation, using materials in this study.

REFERENCES

Aboagye, L. M., A. Isoda, H. Nojima, Y. Takasaki, T. Yoshimura and T. Ishikawa 1994 Plant type and dry matter production in peanut *(Arachis hypogaea* L.) cultivars I Varietal differences in dry matter production. *Jpn. J. Crop Sci., 63: 289-297*

Aboagye, L. M., A. Isoda, H. Nojima, Y. Takasaki, T. Yoshimura and T. Ishikawa 1995 Plant type and dry matter production in peanut *(Arachis* hypogaea L.) cultivars II. Varietal differences in radiation interception. *Jpn. J. Crop Sci., 64: 73-77*

Brougham, R. W. 1956 Effect of intensity of defoliation on regrowth of pasture. *Aust. J. Agric.* Res., '7: *377-387*

Horikoshi, T., N. Homma and S. Ishizaki 1976 Studies on the cultivation of medicinal plants. VII On the growth and yield of *Bupleurum falcatum* L.. *Eisei Shikenjo Hokoku, 94:* 166-169

Isoda, A., T. Yoshimura, T. Ishikawa, H. Nojima and Y. Takasaki 1994 Solar radiation penetration and distribution in soybean communities. *Jpn. J. Crop Sci.,* 63: 298-308

Kim, K. S., N. S. Seong, Y. H. Chang, S. T. Lee, J. I. Lee, H. C. Oak and Y. A. Chae 1995 Variation of plant characters and correlation analysis of its in *Bupleurum falcatum* L.. *Korean J. Medicinal Crop Sci., 3:* 71-76

Kokubun, M. and K. Watanabe 1981 Analysis of the yield-determining process of field-grown soybeans in relation to canopy structure II Effect of plant type alteration on solar radiation interception and yield components. *Jpn. J. Crop Sci.*, 50: 311-317

Maeda, K. 1993 Groundnut ideotype: Its agrophysiological characteristics and contribution of subsp. *fastigiata. Jpn. J. Crop Sci., 62: 211-221*

Minami, M., M. Sugino, M. Sadaoka, C. Hasegawa, C. Ohe, K. Ashida and K. Ogaki 1995 Physiological response and improvement of tolerance to environmental stress in *Bupleurum falcatum* L. (II) Comparison of sensitivities to dry stress between rosette and bolting plants. *Natural Medicines, 49: 401-408*

Murata, Y. 1981 Dependence of potential productivity and efficiency for solar energy utilization on leaf photosynthetic capacity in crop species. *Jpn. J. Crop Sci.,* 50: 223-232

Shibles, R. M. and C. R. Weber 1965 Leaf area, solar radiation interception and dry matter production by soybeans. *Crop Sci.,* 5: 575-577

Shibles, R. M. and C. R. Weber 1966 Interception of solar radiation and dry matter production by various soybean planting patterns, *Crop Sci., 6: 55-59*

Shimokawa, Y., I. Okuda, M. Kuwano and H. Ohashi 1980 Cultivation and breeding of *Bupleurum falcatum* L. (VI) Geographical variation of *B. falcatum Shoyakugaku Zasshi, 34: 239-244*

Sinclair T. R. and T. Horie 1989 Leaf nitrogen, photosynthesis, and crop radiation use efficiency: A review. *Crop Sci., 29:* 90-98

Sinclair, T. R., T. Shiraiwa and G. L. Hammer 1992 Variation in crop radiation-use efficiency with increased diffuse radiation. *Crop Sci.,* 32: 1281-1284

Tani, T., T. Katsuki, M. Kubo, Y. Okazaki and S. Arichi 1987 Histochemistry. XI). Histological and chemical characteristics of bolting and non-bolting roots of cultivated *Bupleurum falcatum* L.. *Chem. Pharm. Bull., 35: 4530-4536*

Yamamoto, H., H. Honjo, S. Hayakawa, Y. Suzuki and N. Kawada 1996 Seasonal changes in efficiency of solar energy utilization and solar energy conversion in two-rowed barley of warm regions in Japan *Jpn. J. Crop Sci., 65: 207-213*

Yoshida, T. 1979 Growth analysis of late-summer sown barley. *Jpn. J. Crop Sci., 48: 495-501*