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Quantitative Growth Analysis of White and Reddish Sword Bean

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ABSTRACT: Sword bean belongs to the subgenus *Canavalia* in the genus *Canavalia*. White and reddish varieties in sword bean were tested to obtain the basic information for improving the yield, quality, and cultural environments through the quantitative growth analysis. Growing plants were sampled at intervals of 10 days from 20 days after sowing. Whole plant weight increased during the period of 11~20 days after sowing in both varieties. The weight of each organ between two varieties increased similarly except leaf area. Whole plant weight changed more close to pod weight than any other characters. The leaf areas of both varieties increased from 50 days after sowing, var. white displayed S type curved line but var. reddish displayed slow S type curved line. The SGR of whole plant weight in both varieties had 3 maxima and 2 minima, 3 maxima and first minimum were shown at the same period but the second minimum was shown at different period. Both varieties showed bimodal curved line. All SGR of each organ and leaf area were shown the 2 maxima and 1 minimum in both varieties. The changes of SLA and LAR were not remarkable between two varieties but these were united together with the maximum of whole plant weight and root weight. ULAR and ULWR were shown similar in both varieties. Reddish variety was more prosperous in early growth stage than white variety because SLA, LAR and LWR were high. In surplus weight, both varieties increased rapidly during the period of 111~120 days after sowing that was applicable to the maximum SGR of pod weight. Surplus weight of var. white increased markedly during the same period comparing those of var. reddish.

Keywords : sword bean, specific growth rate (SGR), specific leaf area (SLA), unit leaf area rates (ULAR), unit leaf weight rates (ULWR), leaf area ratio (LAR), leaf weight ratio (LWR), surplus weight(S)

The genus *Canavalia* consists of 4 subgenera with 51 species (Smartt, 1990). Sword bean belongs to the subgenus *Canavalia* in the genus *Canavalia*. There are two varieties, i.e., var. *alba* with white seed and flower and *gladiata* with reddish seed and flower. Jack bean (*C. ensiformis* (L.) DC.) in the New World and oblique-seeded jack bean (*C. plagiospermus* Piper) should be treated as a single species together with sword bean (*C. gladiata* (Jacq.) DC.). *C. gladiata* is of Old World origin and is probably derived from *C. virosa* Wight & Arn., which grows wild in tropical Asia and Africa. It is widely cultivated in the East, particularly in India, and has now spread throughout the tropics. It has become naturalized in some areas. It is usually grown as a fodder, green manure or as a cover crop. The young pods and beans are extensively used as vegetables in tropical Asia. It was introduced to Japan on early in 1600s and cultivated to small scale after that time. Even though it is originated from tropic Asia, Japanese have been suffered to establish the acclimatization (Purseglove, 1974).

Gregory (1918) designed the quantitative method at first and proposed that the change of dry weight was depended on the compound interest law. Since Blackman (1919) introduced his method, much emphasis in physiology and ecology has been placed on quantitative growth analysis of plant (Evans & Hughes, 1962; Monsi, 1960; Potter & Jones, 1977; Watson, 1952; Whitehead & Myerscough, 1962; Williams, 1946).

It is only recently that the quantitative analysis of plant growth is applied to crops such as *Raphanus sativus*, *Perilla ocymoides* and some *Allium* species etc. (Hahn & Takano, 1986; Hahn *et al.*, 1986, 1996; Hahn & Oh, 1991; Hahn, 1992). In family *Fabaceae* crops, the growth phase of dwarf red cranberry and boston favorite cultivars were similar, but dwarf red cranberry cultivars was more vigorous during early growth stage and the fruit weight was higher than that of boston favorite cultivars (Kim *et al.*, 1990). Growth was influenced by plant habits and seeding dates in soybean (Kim *et al.*, 1994).

This research was carried out to obtain the basic information for improving the yield, quality and cultural environment by presuming the economy of material production in

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sword bean.

MATERIALS AND METHODS

Experimental materials were var. white (*Canavalia alba*) and var. reddish (*C. gladiata*) of sword bean, seeds were obtained from the farmers in Gongju, Chungnam and Muju, Chonbuk, respectively, on October 1999.

Seeds were disinfected by stirring concurrently with soaking in 70% ethyl alcohol for a minute and 1.5% sodium hyphochlorite solution for 15 minutes and then were soaked to absorb the moisture in distilled water (20 ± 1°C) for 2 hours after scarification of seed coat by surgical blade. They were sowed to 1 cm sowing depth in seedling trays (12 unit, 30.0L × 23.5W × 6.0H cm) on 21 April, 2000 and then seedlings were raised in single-covered polyethylene (PE) film house for 30 days. Seedlings were transplanted with 30 cm intrarow spacing by double line on 1.2 m ridge. Ridge was mulched with black PE film after setting the irrigation equipment. Irometer was set to 20 cm depth and then water was irrigated to maintain 60~70% soil moisture content. Temperature was controlled so as not to be too high by opening the windows of both sides from June to August, and temperature fluctuation was shown in Fig. 1. Insecticides were sprayed 3 times from early to middle growth stage.

Growing plants were sampled at intervals of 10 days from 20 days after sowing. They were separated to each organ individually which was dried at 105°C and 50°C in forced air dryer for 1 and 72 hours, respectively, and then dry weight was measured using digital balance (minimum 0.001 g). Leaves were dried and the dry weight was measured after leaf area was measured using portable leaf area measuring instrument (LI-3000, LAMBDA Instruments Co.). For determination of leaf area and dry weight, 20 plants were collected from the 1st to 3rd, 15 plants from the 4th to 6th and 10 plants after the 7th sampling.

Specific growth rate (SGR, μ), specific leaf area (SLA), unit leaf area rate (ULAR), unit leaf weight rate (ULWR), leaf area ratio (LAR), leaf weight ratio (LWR) and surplus weight (S) were estimated according to the Hahn *et al.*'s method (1986).

RESULTS AND DISCUSSION

Morphological differences between *C. alba* and *C. gladiata* were the colors of flower and seed coat (Fig. 2). The colors of flower and seed coat of *C. alba* were white and, those of *C. gladiata* were reddish (Smartt, 1990).

It was about 13 days after sowing when the seed of both varieties get into sprouting, so each data could be collected at 20 days after sowing (Fig. 3). The dry weights of whole plant, each organ, and leaf area increased from 11 to 20 days after sowing, both varieties changed to be similar except on leaf area. Whole plant weight was the closest to the increment of pod weight among each organ. Therefore, that was shown the great increment rate since pod had developed and then ripped. It was about 90 days after sowing. Leaf area increased rapidly from about 50 days after sowing, var. white displayed S type curved line increasing rapidly on middle growth stage but var. reddish displayed slow S type curved line, which was a little different between two variet-

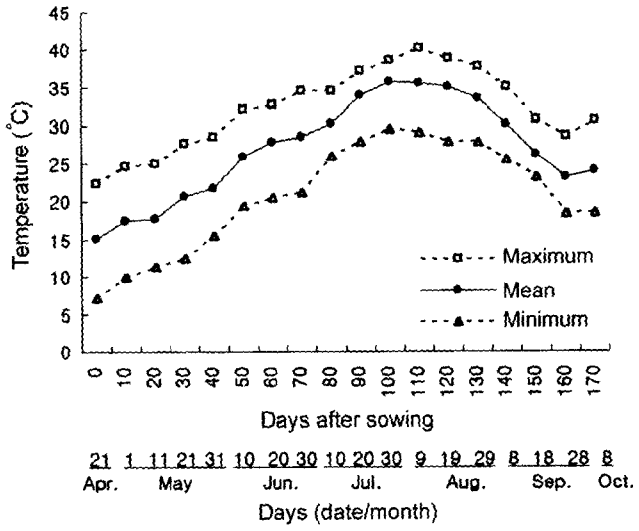

Fig. 1. Fluctuation of air temperatures in single-covered polyethylene film house during the experiments.

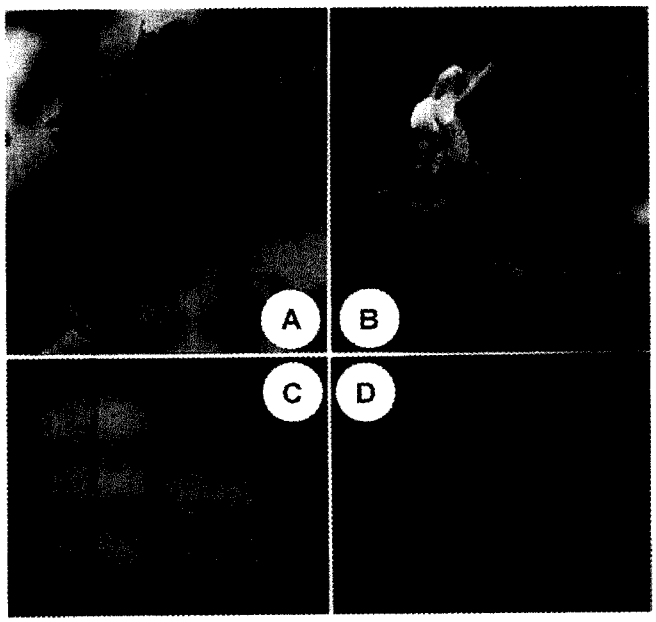

Fig. 2. Flowers (A) and seeds (C) of var. white and flowers (B) and seeds (D) of var. reddish in sword bean.

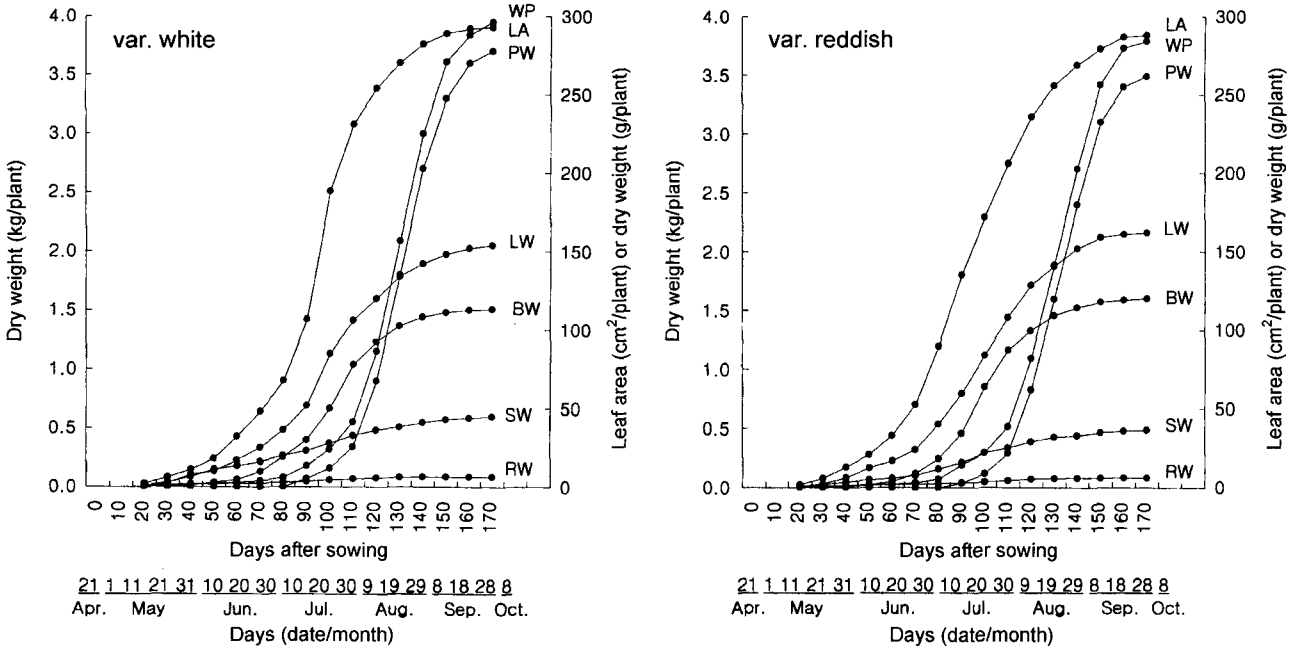

Fig. 3. Changes for the dry weight of a whole plant weight (WP), stem weight (SW), leaf weight (LW), root weight (RW), pod weight (PW), and leaf area (LA) in sword beans grown under single-covered polyethylene film house.

ies. This tendency was similar to that of leaf weight. Branch weight increased from 60 days after sowing and augmentation was low during the period of 131~140 days after sowing, and these displayed S type curved line nearly in both varieties. However, stem and root weights of both varieties increased very gently in comparison with whole plant, leaf, and branch weight, those augmentation was straight line nearly. Pod weight increased very rapidly from 90 days after sowing. Therefore it was observed that the changes of growth in var. white and var. reddish were very similar. Hence var. white may be more prosperous in late growth because whole plant and each organ weight of var. white were less heavier from 90 days after sowing than those of var. reddish.

Deakin (1974) reported that seed color is associated with emergence and seed yield of snap bean. Red seed variety sprouted well at germination and grew vigorously at early growth stage, which resulted in the higher yield at harvesting than white seed variety. This is a good agreement with the result by Lee (1974). In this experiment, it was not identified what was factors of seed color or growth between var. white and var. reddish. Further experiments should be needed to characterize the factors.

The specific growth rate (SGR, μ) of whole plant weight, each organ weight and leaf area were shown in Fig. 4. The most SGR of both varieties was very similar. Whole plant weight correspond well between two varieties having 3 maxims and 2 minims, the first maximum appeared during the period of 21~30 days after sowing and then it dwindled, the second and third maximum appeared during the period of 91~100 and 121~130 days after sowing, respectively. After the first maximum, both varieties shown the first minimum during the period of 51~60 days after sowing. However those were shown differently in the second minimum, var. white shown during the period of 101~110 days after sowing and var. reddish shown during the period of 111~120 days after sowing.

The fluctuation of SGR was shown differently according to the cultural environment and sampling period as well as the kind of crops (Evans & Huhges, 1962; Hahn & Takano, 1986; Hahn *et al.* 1986; Hunt, 1982; Potter & Jones, 1977; Watson, 1952), both varieties shown the bimodal curved line in this experiment. In case snap bean plant was sampled at intervals of 7 days, the first maximum was shown during the period of 15~21 days after sowing which was prosperous period of root development, the second maximum was shown during the period of 29~35 days after sowing which was not only flowering but also thickening growth stage of pod (Takano *et al.*, 1981). Other crops like perilla, snap bean, and cotton showed the bimodal curved line (Hahn *et al.*, 1996; Kim *et al.*, 1990; Petterson *et al.*, 1978). However Radish showed the mono-modal curved line (Hahn & Oh, 1991); therefore it is presumed that crops have the mono- or bimodal curved line according to their characters.

In the SGR of leaf weight, the first maximum was shown during the period of 21~30 days after sowing in both variet-

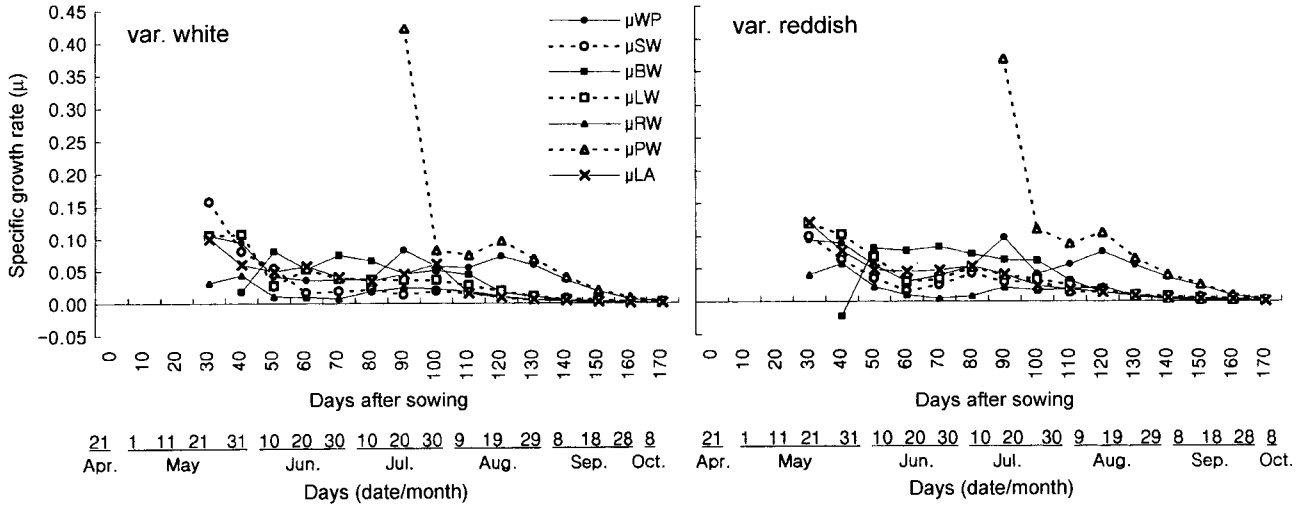

Fig. 4. Changes for the specific growth rate of a whole plant weight (WP), stem weight (SW), leaf weight (LW), root weight (RW), pod weight (PW), and leaf area (LA) in sword beans grown under field single-covered polyethylene film house.

ies but the second maximum and first minimum were shown differently between two varieties. It was different from 10 to 20 days. In the SGR of root weight, both varieties looked similar. The first maximum was shown during the period of 31~40 days after sowing, the first minimum was shown during the period of 61~70 days after sowing. The second maximum was shown during the period of 81~90 days after sowing and then it dwindled. In the SGR of pod weight, two varieties showed the first and second maximum during the period of 91~100 and 111~120 days after sowing, respectively. The SGR of leaf area showed very similar between var. white and var. reddish. In this experiment, both varieties showed the first maximum of leaf weight, root weight, and leaf area during the period of 21~40 days after sowing, those of whole plant weight and pod weight were shown during the period of 8190 days after sowing. The second maximum was shown during the period of 111~120 days after sowing. This period correspond with the first maximum of pod weight, which was consistent with previous studies in snap bean and cotton (Kim *et al.*, 1990; Patterson *et al.*, 1978).

The specific leaf area (SLA), unit leaf area rate (ULAR), unit leaf weight rate (ULWR), leaf area ratio (LAR) and leaf weight ratio (LWR) of var. white and var. reddish were shown in Fig. 5. The changes of SLA and LAR were differ-

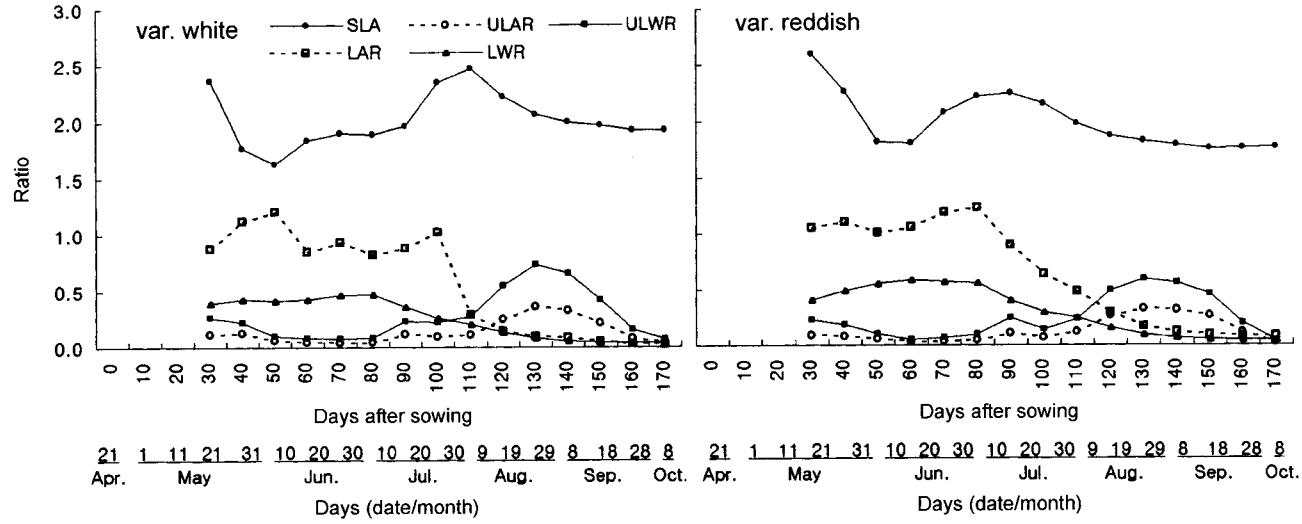

Fig. 5. Changes for specific leaf area (SLA), unit leaf area rate (ULAR), unit leaf weight rate (ULWR), leaf area ratio (LAR), leaf weight ratio (LWR) in sword beans grown under field single-covered polyethylene film house.

ent between var. white and var. reddish. The second maximum of SLA was shown during the period of 81~90 days after sowing in var. reddish, while it was shown during the period of 101~110 days after sowing in var. white. The first maximum of LAR in var. white was shown during the period of 41~50 days after sowing and that was decreased remarkably during the period of 101~110 days after sowing, var. white was more different than var. reddish. The change of LAR in var. reddish increased gently until 80 days and then decreased gently after that times compared to that of var. white. The maximum in two varieties was agreed with the SGR of whole plant weight and root weight (Fig. 4).

In the ULAR of two varieties, the difference was small, the first and second maximum were shown during the period of 81~90 and the period of 121~130 days after sowing, respectively. ULWR was similar between two varieties. The growth patterns may be similar because the fluctuations of ULAR and ULWR correspond well between var. white and var. reddish. However var. reddish was higher than var. white in SLA, LAR LWR except ULWR and ULAR, it means that var. reddish more flourished in early growth than var. white (Deakin, 1974; Kim *et al.*, 1990).

In quantitative growth analysis, ULAR and ULWR are the physiological index in relation to photosynthesis, but ULWR is more suitable because broad-leave plant was in short supply of light-interception on inferior leaves in case which was cultivated under PE film house. ULAR and ULWR correspond well in perilla and snap bean (Hahn *et al.*, 1986; Kim *et al.*, 1990). Also in this experiment, the first and second maximum and the first minimum were shown during the period of 21~30, 121~130 and 61~70 days after sowing, respectively, which correspond well between var. white and var. reddish.

For surplus weight that is presumptive index to amount of accumulated translocation of photosynthate, var. white has shown the second maximum during the period of 121130 days after sowing since it showed the first maximum during the period of 31~40 days after sowing. However var. reddish has shown the third maximum during the period of 131~140 days after sowing since it showed the first and second maximum during the period of 31~40 and 91~100 days after sowing. Therefore var. white differed little with var. reddish in surplus weight. It was increment period during the period of 111~120 days after sowing and var. white was little heavier in late growth stage than var. reddish (Fig. 6). The rapid increment of surplus weight was observed at substantial process of plants (Evans, 1972; Hunt, 1982; Monsi, 1960; Patterson *et al.*, 1978; Potter & Jones, 1977; Williams, 1946), which correspond to the maximum period of pod, and two varieties correspond well.

Considering the above results, var. white and var. reddish

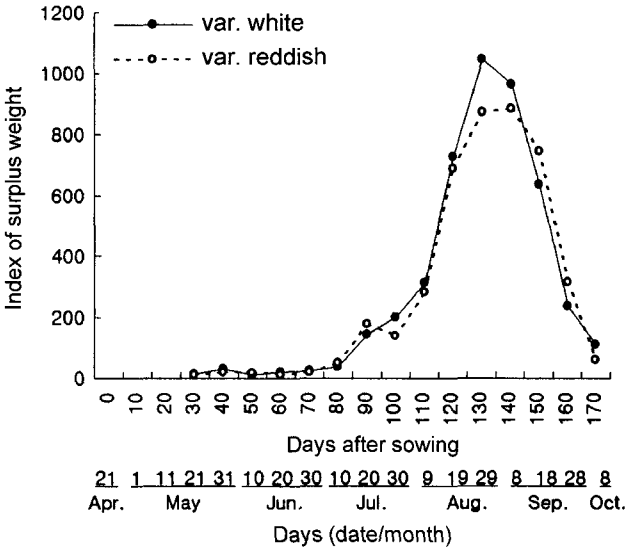

Fig. 6. Changes for the surplus weight in sword bean grown under field single-covered polyethylene film house.

were similar in growth pattern. But var. reddish perhaps has higher yield than var. white, because var. reddish plant prospers at early growth stage, vigor is strong and SGR of pod is high. In cultural practice, the maximum of whole plant weight and each organ weight except pod weight were shown during the period of 21~30 and 81~90 days after sowing, respectively. Late period correspond with the maximum of pod weight; it was come under the second maximum of ULWR and the rapid filling stage of surplus weight. Therefore it may be necessary for fertilization and management at this period.

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