Time-Space Flowering and Podding Characterization in Erect-growing Summer Mung Bean—Vigna radiate L.

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**Abstract**

The flowering and podding sequences and patterns in different Mung bean varieties were studied by examining the flowering and podding of Xilv 1 and Anlv 7, in order to provide a basis for Mung bean hybridization and high efficiency production. It was shown that the flower period of Mung bean could be divided into initial, full bloom, final stages, and secondary full bloom and final stages. Flowers mainly distributed at nodes 6-8 at the initial flowering stage; distributed at all plant nodes, especially at the nodes on lower branches at the full bloom stage; and sporadically distributed at the final flowering stage. The flowering sequence of Mung bean was that they began to flower on the first inflorescences developed from *axillary buds* and then flowered first at proximal nodes on lower branches, then at nodes on relatively upper branches, and finally at nodes on top branches. There were the highest numbers of open flowers and fructifying pods on lower branches, followed first by those on relatively upper branches and finally by those on top branches.

**Background**

The flower number and podding rate of Mung bean (*Vigna radiate* L.) are the determinant factors to its yield (Mondal 2007). Although Mung bean is capable of flowering in great quantities, it sheds off great numbers of its flowers and pots, which limits its yield increase (Saitoh 2004; Islam et al. 2010). High yield varieties of Mung bean set greater numbers of flowers than low yield varieties and the yields of the formers are extremely significantly positively correlated with their pod and flower numbers and extremely significantly negatively correlated with their propagation efficiencies (Mondal 2013; Ashrafuzzaman 2013; Singh 2014). Leguminous crops are characterized by a highly varying flowering period, which determines their pod maturities to some extent (Egli and Bruening 2006). The flower and pod distributions over time determine use efficiencies of assimilates by kernels, which lays down a basis for yield increasing (Erkut 2007). Bruening and Egli (2000) held that in leguminous crops, limited yields were because early rapid pod and kernel growths consumed a major part of assimilates, thus forming a heavier weight than pods and kernels set late in the growing season (Begum et al. 2007; Fakir 1997). In soybean, the earlier flowering starts, the slower pods and kernels develop, which is conducive to a consistent pod maturity (Ltd 2004). The greater numbers of flowers does Mung bean form over 14–21 days after flowering, the more pods it will keeps and then the higher its kernel yield will be when it reaches its maturity (Mondal et al. 2009). In varieties with a long flowering period, pods tend to mature over a relatively long time, which is not favorable for harvesting. In order to make Mung bean mature over as short a time as possible, it is better to adopt such varieties that have less shoots and flower in great quantities over 10-15 days after flowering (Mondal et al. 2011; Iqbal et al. 2015).

Pods at same nodes are easy to affect one another (Egli 2005), and pods at different nodes are relatively independent (Heitholt et al. 1986). At same nodes, the flower shedding rates at the base of the primary raceme, which occurs earlier, are lower than those of the secondary and tertiary racemes, which occurs later (Brun and Betts 1984; Heitholt et al. 1986). At same nodes of a plant, the abortion rates of early flowers and pods are much lower than those of the late ones (Huff and Dybing 1980; Brun and Betts 1984;
Tambal 2000). These results indicate that the flowering and podding pattern of Mung bean is of great significance to increasing possibilities of successful hybridization, developing varieties that set pods over a short time and yield increasing. However, there have been fewer researches on the flowering and podding pattern of time and space of Mung bean. Accordingly, the study presented in the paper researched on the flowering and podding pattern of time and space of Mung bean with two erect growing varieties of Mung bean in order to characterize flowering and pod setting of Mung bean in the field.

**Materials And Method**

**Materials**

Currently, newly-developed varieties as well as promoted and adopted varieties in Mung bean production all grow erect (Bain et al., 2007), so that the study chose Xilv 1 and Anlv 7, two erect-growing varieties of Mung bean, as its trial materials.

**Experiment Design**

The study carried out its experiment on Experiment Farming No.1 (108°E. and 34°N.) standing on the North Campus of the Agriculture & Forestry University in Yangling, Shaanxi, China in 2017–2018 and immediately before the experiment, wheat had been planted on its farmland lot. In the experiment, the two varieties were planted at the same row and plant spaces of 40 cm and 16.7 cm, respectively, and the planting density of 150 000 plants per hm. Mung bean planting was done in middle June and conventional field management practices were adopted.

**Measurements and measurement methods**

Before flowering, 15 normally- and consistently-growing plants of the two varieties were selected and tagged in the central part of their plots. The numbers and positions of newly opened flowers of the tagged plants were counted every day from their beginning to flower until flowering ceased and then accordingly a flowering pattern diagram was drawn for all these plants. During the maturing period, the numbers of fructified pods of the plants at all the different nodes were counted and then based on the numbers thus obtained, the vertical distributions of the fructified pods were calculated.

The **Percentage of fructified pods** = (the number of fructified pods / the number of flowers) × 100

**Results**

**Daily numbers of newly opened flowers per plant**

It can be seen from the daily numbers of newly-opened flowers per plant presented in Fig. 1 that the daily numbers of newly-opened flowers per plant presented a pattern characterized by “a small flower number—a large flower number—a small flower number—a larger flower number—a smaller flower number. Depending on their daily numbers of newly-opened flowers, the flowering periods of the two varieties were divided
into five stages, initial, full-bloom and final stages, and secondary full-bloom and final stages. It can be seen from Table 1 that the initial flowering stage was short, lasting 2–4 days and at this stage the daily number of newly opened flowers numbered less than two; the full bloom stage lasted more than ten days and at this stage the daily number of newly opened flowers per plant increased day by day to more than 3; the final flowering stage lasted 9–12 days, and at this stage, the daily number of newly opened flowers numbered less than two on average; then there came the secondary full bloom stage of about 10 days at which the daily number of newly opened flowers per plant somewhat increased, amounting to about 3; and then there came the secondary final flowering stage, which lasted about 3 days.

The two varieties greatly differed in their flowering period and daily numbers of newly opened flowers. In 2017, the daily numbers of newly opened flowers per plant at the full bloom and secondary full bloom stages of Xilv 1, which lasted 19 days and 9 days, were 87.3 and 20.3, respectively; and daily numbers of newly opened flowers per plant at the full bloom and secondary full bloom stages of Anlv7, which lasted 10 days and 12 days, were 82.5 and 47.6, respectively. The proportions of open flowers per plant at the full bloom stage to the total number of open flowers per plant at flowering period of Xilv 1(72.8%) was higher than those of Anlv 7(54.7%). In 2018, the daily numbers of newly opened flowers per plant of Anlv 7 at the full bloom stages, which lasted 12 d days, was 62.9, making up 51.9% of the total number of open flowers per plant during the flowering period, and the daily numbers of newly opened flowers per plant of this variety at the secondary full bloom stages was 43.34, making up 29.1% of the total number of open flowers per plant during the flowering period; and Xilv 1 had a full bloom stage of 25 days but did not saw its secondary full bloom and final flowering stages.

Table 1. Daily numbers of newly opened flowers of the different Mung bean varieties at the different flowering stages
| Year | Variety | Flowering stage | Date       | Daily number of newly opened flowers per plant | Total number of open flowers per plant | proportions of open flowers per plant at the full bloom stage to the total number of open flowers per plant |
|------|---------|-----------------|------------|-----------------------------------------------|--------------------------------------|--------------------------------------------------------------------------------|
| 2017 | Xilv1   | Initial flowering stage | 7.23-7.24  | 1.2                                           | 2.3                                  | 1.9                                                                                  |
|      |         | Full bloom stage   | 7.25-8.12  | 4.6                                           | 87.3                                 | 72.8                                                                                 |
|      |         | Final flowering stage | 8.13-8.21  | 0.9                                           | 7.9                                  | 6.6                                                                                  |
|      |         | Second Full bloom stage | 8.22-8.30  | 2.3                                           | 20.3                                 | 16.9                                                                                 |
|      |         | Second final flowering stage | 8.31-9.2   | 0.7                                           | 2.1                                  | 1.8                                                                                  |
|      | Anlv7   | Initial flowering stage | 7.23-7.26  | 2.8                                           | 11.3                                 | 7.5                                                                                  |
|      |         | Full bloom stage   | 7.27-8.5   | 8.3                                           | 82.5                                 | 54.7                                                                                 |
|      |         | Final flowering stage | 8.6-8.17   | 0.6                                           | 7.3                                  | 4.8                                                                                  |
|      |         | Second Full bloom stage | 8.18-8.29  | 4.0                                           | 47.6                                 | 31.5                                                                                 |
|      |         | Second final flowering stage | 8.30-9.1   | 0.7                                           | 2.2                                  | 1.5                                                                                  |
| 2018 | Xilv1   | Initial flowering stage | 7.31-8.2   | 0.6                                           | 1.8                                  | 2                                                                                   |
|      |         | Full bloom stage   | 8.2-8.26   | 3.4                                           | 84.1                                 | 95                                                                                   |
|      |         | Final flowering stage | 8.27-9.7   | 0.3                                           | 2.6                                  | 3                                                                                   |
|      | Anlv7   | Initial flowering stage | 7.31-8.2   | 1.2                                           | 3.5                                  | 2.8                                                                                 |
|      |         | Full bloom stage   | 8.3-8.14   | 5.4                                           | 64.5                                 | 51.9                                                                                 |
|      |         | Final flowering stage | 8.15-8.27  | 1.2                                           | 16.9                                 | 13.6                                                                                 |
|      |         | Second Full bloom stage | 8.28-9.6   | 3.6                                           | 36.2                                 | 29.1                                                                                 |
|      |         | Second final flowering stage | 9.7-9.8    | 1.6                                           | 3.1                                  | 2.5                                                                                 |

Time and space distribution of Plant flowers in the Mung bean Varieties

In the Mung bean Varieties, flowers of the plant at the different flowering stages distribute differently. It can be seen from Fig. 2 that at the initial flowering Stage, the flowers of the plant mainly distribute in its...
middle main stems, i.e. middle 6–10 node in Xilv 1 and 4–9 nodes in Anlv 7. At the full bloom stage, flowers of the plant distributed more widely, with more flowers located on lower branches of its main stems. In Anlv 7, flowers of the plant scattered sporadically at different nodes of its main stems at the final flowering stage and in Xilv flowers of the plant scattered sporadically at different nodes of its main stems at nodes where flowering occurred most early and on lower branches at the same flowering stage.

Flowering Sequences of the Plant

It can be seen from Fig. 3 that summer planted Mung bean presented a consistent flowering sequence. It was observed that the plants generally had 16 main stem nodes, and flowers of branches at stem nodes 6–8 opened first, so that these nodes were the flowering-onset nodes; and then inflorescences from axillary buds at proximal nodes on these lower branches began to flower and subsequently flowers of branches at stem nodes 9–11 began to open; then the remaining unopened flowers of the branches progressively opened from proximal nodes to distal nodes, with the flowers at their terminal ends finally opening. Plants began to flower at the flowering-onset stem nodes and progressively did so at the stem nodes above and below the flowering onset stem nodes; and they flowered from the proximal nodes to the distal nodes on their branches, which flowered alternatively; and as a whole, they flowered first at their middle parts, then at their lower parts and finally at their upper parts.

Flowering and podding characterizations at different plant nodes

Mung bean can set pods everywhere on its plants, but its flowers and pods differentially distributed vertically, with the former mainly in upper plants. In summer Mung bean, plants had the highest numbers of open flowers and fructifying pods on their primary branches, and there were lower numbers of fructify pods at their flowering onset stem nodes and somewhat increased numbers of fructifying pods at stem nodes above the flowering onset stem nodes. It can be seen from Fig. 4 that in Xilv 1, there was the highest number of opened flowers on the branches at both stem nodes 2 and 3, reaching 24.5, and the lowest number of opened flowers on the branches at the upper stem nodes, reaching 0.3. It can be seen from Fig. 5 that in both Anlv 7 and Xilv 1, there were the highest number of opened flowers on the branches at stem node 2, reaching 17.1 and 14.5, and the lowest numbers of opened flowers on the branches at stem node 6, reaching 2.4 and 1.5, respectively.

As an important yield-affecting parameter, the pod fructifying rates at different nodes varied within 29.17% - 78.46%. In summer Mung bean, there were higher numbers of open flowers and fructifying pods on branches at the lower stem nodes and lower numbers of open flowers and fructifying pods at the upper stem nodes, which probably resulted from insufficient nutrient supplies to pods on branches at the upper stem nodes. In Xilv 1, there was the highest pod fructifying rates on branches at stem node 1, followed first by those at relatively upper nodes and then by those at flowering onset stem nodes and upper stem nodes. And the pod fructifying rates varied less in Anlv 7 than in Xilv1 and peaked on the branches at stem node 4, reaching 77.58%.

Flowering and podding characterization by plant
Pods develop from ovaries and thus the flower number per plant is the major contributor to bigger differences in fructified pod number. It can be seen from Table 2 that the flower and pod numbers of Xilv 1 and Anlv 7 differed greatly, standing at 63.9% and 67.2%, respectively. Anlv 7 had higher numbers of opened flowers and fructified pods and higher poding rates per plant than Xilv 1.

| Material | Flowers per plant | Pots per plant | Pot setting rate per plant (%) |
|----------|-------------------|---------------|-------------------------------|
| Xilv 1   | 79.5±13.1         | 50.8±2.5      | 63.9±4.0                      |
| Anlv 7   | 96.9±11.1         | 65.1±4.7      | 67.2±5.0                      |

Table 2. Flower and pod numbers per plant and podding rates per plant in the different Mung bean varieties

Discussion

In Leguminous crops, flowering and podding are dynamic processes and whether pods can be formed and kept until their maturity or not is dependent on when and where they develop (Egli and Bruening 2006). Genotypes, which open more flowers over 10–15 days after their initial flowering stage, had a higher yield (Fakir et al. 2011). Saitoh et al. (2004) believed that cultivated and wild types of soybean flowered upward from basal racemes. Zhao (2013) held that varieties with a determinate flowering habit began to flower first in their middle stems and then flowered both upward and downward from there, and varieties with an indeterminate flowering habit first began to flower in their central stems (stem nodes 7–10) and flowered upward and downward from there first to their upper stems and then to the lower stems 2–3 days after their initial flowering stage. Jin (1989) believed that erect growing types of adzuki bean began to flower at and around stem node 6, and then flowered upward and downward and their branches alternatively flowered from their bases to their tops. The study indicated that like the flowering pattern of adzuki bean, Mung bean very sequentially flowered, first on its middle branches (at stem nodes), then on its lower branches and finally on its upper branches, and presented a normal distribution characterized by a small daily flower number—a large daily flower number—a small daily flower number. In Mung bean, the vegetative growth, flowering and kernel filling durations were in a negative proportion to the temperature as an important environmental factor that determine the reproductive growth (Begum et al. 1998; Roknuzzaman et al. 2007). However, Zhang (2002) found that there were no temperature effects on the flowering duration but there were more flowers to open at the late flowering stage under a high temperature. The study found that Mung bean, if there occurred a higher rainfall at the late podding stage, humid and hot conditions were prone to make the secondary full bloom stage and final flowering stage appear, but the durations of and the flower numbers at these two stages would be shorter and lower than those of and at the first full bloom stage and final flowering stage, respectively. In response to a rainfall of 168 mm in September of 2017 and a rainfall of 55 mm in the same month of 2018, Xilv 1 had its secondary bloom stage only in the lower rainfall year of 2017, and Anlv 7 had its secondary full bloom stage in both of the two year; this indicate that Anlv 7 was more rainfall sensitive.
Zhang (1992) revealed that in Mung bean, the lowest nodes at which there were open flowers were nodes 2–5 and the flower and pod shedding percentage were more than 30%, believing that nutrient transports were the major factor to affect flower and pod shedding off and environmental conditions obviously affected the flower numbers at different nodes (Jiang and Egli 1993; Egli 2010). This study found that there were more flowers and pods, and higher fructifying pods on lower branches. Flowers during the late growth make a very small contribution to the final yield (Ojehomon 1970; Subhadrabandhu et al. 1978); and lower pod numbers at upper nodes probably result from an insufficient nutrients transports to upper flowers and pods of plants, but the details of this cause needed to be further studied.

**Conclusion**

In Mung bean, the flowering period could be divided into initial stage, full bloom stage, final stage, secondary full bloom stage and secondary final stage in terms of the daily flower numbers per plant. Different varieties of Mung bean differed greatly at the full bloom flowering stage and were prone to have its secondary full bloom and final flowering stage with a higher rainfall; and the flower numbers at and the durations of the secondary full bloom and final flowering stages were lower and short than those at and of the full bloom and final flowering stages, respectively. Generally, Mung bean began to flower at stem nodes 6-8 and then flowered upward and downward from there, and its branches alternatively flowered from their bases to their tops. In Mung bean, the numbers of open flowers and fructifying pods on lower branches were the highest, followed first by those on relatively upper branches and then by those on top branches. The podding rates at different nodes on lower branches were higher than those on upper branches and the podding rate per plant stood at about 65%.

**Declarations**

**Ethics approval and consent to participate**

Not applicable.

**Consent for publication**

Not applicable.

**Availability of data and materials**

All data generated or analysed during this study are included in this published article.

**Competing interests**

The authors declare that they have no competing interests.

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**Authors contributions:** N W, J Z, XI G designed this work and prepared the first draft of the manuscript. Md H, Y F, Yn Z and HQ W collected field data. P Y, Jf G and XI G revised and approved the submitted version of the manuscript. All authors read and approved the final manuscript.

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Figures
Figure 2

Daily numbers of newly opened flowers of the summer planted varieties
Note: The numbers in ☐ are the flowering order of the first-opened flower of the plant. ☐ stands for flowers at the initial flowering stage, ☐ stands for flowers at the full-bloom stage, and ☐ stands for flowers at the final flowering stage; and the numbers in these three symbols are the average flower numbers per node on different branches at the three flowering stages, respectively.

Figure 4

Flowering and podding patterns of the Mung bean varieties.
Note: The numbers in \(\bigcirc\) are the orders of the first opened flowers at stem or branch nodes.

Figure 6

Flowering trees of the two varieties

Figure 8

Flower and pod numbers per node of Xilv 1
Figure 10

Flower and pod numbers per node of Anlv 7