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# Botanical Studies on *Phaseolus vulgaris* L. I-Morphology of Vegetative and Reproductive Growth

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**Abstract:** In this study morphological information is produced as evidence for proper delimitation of *Phaseolus vulgaris* L. taxonomy. The field work was carried out during the summer season of 2009 to follow the vegetative and reproductive morphology of studied plant throughout the successive stages of its entire life span. Germination of seeds and yield components at harvest time was also under consideration. Such knowledge may fulfill information acquisition in this concern. The morphology of vegetative growth includes: plant height, length of the main stem, number of internodes of the main stem, length and diameter of successive internodes of the main stem, number of secondary branches developed per plant, lengths of secondary branches of mature plant, fresh weight of leafless shoot per plant, dry weight of leafless shoot per plant, number of leaves per plant, total leaf area per plant, fresh weight of leaves per plant and dry weight of leaves per plant. Moreover, keen observations and descriptive morphology of the root and shoot system were under consideration. The morphology of reproductive growth includes: flower bud differentiation, full blooming, fruit set and maturity, fresh weight of reproductive organs and dry weight of reproductive organs. In addition, the yield characters at harvest time were investigated i.e., number of matured dry pods per plant, number of seeds per pod, number of seeds per plant, dry weight of pods per plant, yield of matured dry seeds per plant and specific weight of seeds.

**Key words:** *Phaseolus vulgaris* L., kidney bean, fabaceae, seed germination, morphology, vegetative growth, reproductive growth

## INTRODUCTION

The legumes have been traditionally treated as one large, somewhat heterogeneous family, the Leguminosae. Hutchinson (1973) and Cronquist (1981) agree that the group is perhaps best split into three separate families of the order Fabales: Mimosaceae, Caesalpiniaceae and Fabaceae (Papilionaceae). The order has 590 genera and 13200 species and is cosmpolitan in distribution.

Rendle (1967), Hutchinson (1973), Cronquist (1981) and Jones and Luchsinger (1987) mentioned that Fabaceae consist of about 440 genera and 12000 species. They are distinguished by the legume and the usually papilionaceous flowers. In economic importance, the family is second only to the grasses (Poaceae). Plants of the family are of considerable importance as a source of high-protein food, oil and forage as well as ornamentals and other uses. Fabaceae occur allover the world but particularly in the warm temperate regions of both the Northern and Southern Hemispheres.

Although the family is well defined by its floral and fruit characters, there is a considerable range of anatomical variation, which is largely correlated with the wide diversity of habit shown by the different genera and species. Other anatomical variations are xeromorphic in nature. Some anatomical characters are common to a very wide range of genera, but none of them are sufficiently distinctive to demarcate the Papilionaceae from all other families at a glance (Metcalfe and Chalk, 1979). In this connection, Cronquist (1981) as well as Rubatzky and Yamaguchi (1999) mentioned that the Fabaceae are one of the more sharply defined and readily recognizable large families of flowering plants. In counterpoint, the genera are ill defined and frequently confluent. Thus, any new botanical information about Fabaceous genera are urgently to be welcomed.

The present study is confined to *Phaseolus vulgaris* L., being an important vegetable crop of the genus *Phaseolus*.

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*Phaseolus* is a well known genus of the family Fabaceae with more than 150 species. Bailey (1969) described the genus *Phaseolus* as follows: A wide range of annuals and perennials, mostly in warm and tropical countries, usually herbs but a few woody at base, grown somewhat for ornament but mostly for edible seeds and pods; the known species are probably 150-200, when the extensive synonymy shall have been reduced. Mostly twining, some forms erect. Leaves pinnately 3-foliolate but sometimes reduced to 1 leaflet, stipulate and stipellate, the stipules persistent, leaflets entire. Flowers few to many, racemose or fascicled on axillary peduncles, white, yellow, red, purple, papilionaceous, closely subtended by 2 bracts like an outer calyx which are sometimes deciduous; lobes of calyx equalling or exceeding its tube; keel coiled, being the distinctive mark of the genus; stamens 9 and 1; style bearded longitudinally. Pods compressed or with convex sides, several-to many-seeded, dehiscent; germination hypogeal or epigeal.

*Phaseolus vulgaris* L., the subject of the present investigation, is the best known and most widely cultivated species of the genus *Phaseolus* (Shukla and Misra, 1979; Purseglove, 1988). *Phaseolus vulgaris* L. is of New World origin and it was taken to Europe in the 16th century by the Spaniards and Portuguese and it reached England in 1594. They also took it to Africa and other parts of the Old World. It is now widely cultivated in many parts of the tropics and subtropics and throughout the temperate regions. They are grown for their immature edible pods and for the dry ripe seeds and to a lesser extent for green-shelled beans. The leaves are used as a pot-herb in some parts of the tropics. In Latin America and parts of tropical Africa they furnish a large part of the protein food of the inhabitants, being grown mainly for the dried pulse. They are little grown in India, where the people prefer their own, better-known pulses. In Europe, the United States and other temperate countries they are grown mainly for the green immature pods which are eaten as a vegetable and are also canned and frozen. The whole dried beans are also cooked with tomato sauce and canned and are usually known as baked beans. The straw is used as forage. The English name of *Phaseolus vulgaris* L. is called Common bean or Kidney bean; it is also known as French bean, Haricot bean, Salad bean, Runner bean, Snap bean, String bean and Frijoles (Singh, 1999; Pandey, 2003).

The present study intends to introduce a detailed botanical information about the external morphology of vegetative and reproductive growth of *Phaseolus vulgaris* L. plant throughout the consecutive stages of its entire life span. This would be an effort to proper delimitation of this species in the family Fabaceae and even more such knowledge would be useful to specialists in various aspects of biology of such important plant.

## MATERIALS AND METHODS

The current investigation was performed on Kidney bean plant (*Phaseolus vulgaris* L. cv. Giza 6) of the family Fabaceae. Seeds were secured from Department of Vegetable Research, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt.

A germination test of seeds was carried out in Department of Seed Testing, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt according to the International Rules for Seed Testing Association (ISTA, 1985).

**Field work procedure:** The field work was carried out in the Agricultural Experiments and Researches Station, Faculty of Agriculture, Cairo University, Giza, Egypt during the summer growing season of 2009 to provide the experimental plant materials. Date of cultivation was May 12th, 2009. The trial included five replicates, each represented by one plot. The plot was 4×5 m with eight ridges 60 cm apart. Seeds were sown in hills, spaced 25 cm, on one side of the ridge. The plants were later thinned to two plants per hill. All field practices were carried out as recommended for the studied crop in the vicinity.

**Observations and recording of data:**

**Vegetative growth:** Ten plants, two plants from each of the five replicates, were assigned for follow up the vegetative growth of Kidney bean plants at two-week intervals. At each sampling date, the root and shoot systems were described morphologically. The branching system of the shoot was followed up to determine the plant habit of growth. The following measurements were recorded fortnightly for the shoot:

- Plant height; cm, measured from cotyledonary node up to the upper most point of the plant
- Length of the main stem; cm, measured from the cotyledonary node up to the shoot apex
- Number of internodes of the main stem
- Length (cm) and diameter (mm) of successive internodes of the main stem of mature plant
- Number of secondary branches per plant
- Lengths of secondary branches, cm, of mature plant.
- Fresh weight of leafless shoot, g
- Dry weight of leafless shoot, g. Dry weight of this character and those mentioned later on were carried out in an oven at 70°C till a constant weight was reached; almost 48 h

- Number of leaves per plant
- Total leaf area per plant, $cm^2$. Leaf area was measured by means of LI-3000 A portable area meter, LI-3050 A Transparent belt conveyer-of LI-Cor, Inc., Lincoln, Nebraska, USA
- Fresh weight of leaves per plant, g
- Dry weight of leaves per plant, g

**Reproductive growth:** Reproductive growth was followed up during the experimental season. Flowering period of Kidney bean plant was determined i.e., dates of onset and end of flowering were recorded. Time taken for different reproductive developmental stages was fixed i.e., flower bud differentiation, full blooming and fruit set and maturity. In addition, the following yield characters were recorded at harvest time on 25 plants, 5 plants from each replicate.

- Number of matured dry pods per plant
- Number of seeds per pod
- Number of seeds per plant
- Dry weight of pods per plant, g
- Yield of mature dried seeds per plant, g
- Specific weight of seeds (average weight of 100 seeds, g)

Data of the present investigation were subjected to various conventional methods of statistical analysis according to Snedcor and Cochran (1982).

## RESULTS AND DISCUSSION

**Germination of seeds and seedling growth:** After sowing of seeds, germination takes place. Seeds imbibe water as a first step leading to germination. As a result, the seed testa become softened and swell then ruptured. This is followed by the emergence of the radicle through the seed coat. This occur after 16 h of sowing. Seed germination of Kidney bean is epigeal, the hypocotyl elongates and raises the two cotyledons above the ground accompanied by the partially enveloping remains of the seed. Cotyledons are small in size, fleshy, yellow-green in colour and reniform in shape. The hypocotyl is curved inside the soil then straightens above the ground. This take place when seedling is 6 days old. The hypocotyl is slenderical in shape and pale-green in colour. By now; the plumule is also upward; the secondary roots develop as seedling is 7 days old. At the age of 10 days, the first two foliage leaves (the prophylls) are formed (Fig. 1). The cotyledons fall when seedling is 12-14 days old and the prophylls are completely developed. At this age, seedling stage comes to an end. The two prophylls are oppositely

Fig. 1: A photograph of *Phaseolus vulgaris* L. seedling, 10 days old, showing its epigeous pattern of growth where the two cotyledons are brought above the soil. The first two foliage leaves (the prophylls) are developed at opposite position

arranged, cordate in shape, entire margin, acute apex, reticulate pinnate venation and green in colour. The radicle averages 6.2 cm and the hypocotyl is some 4.8 cm long.

The rules of germination given by ISTA (1985) were followed. The germination speed (after 5 days) and the germination capacity (after 8 days) were identical, being 91.7% indicating that the viability of Kidney bean seeds is high.

**External morphology of the root system:** The primary root of Kidney bean starts its development from the radicle at the lower end of the hypocotyl of the embryo. Directly below the hypocotyl, the radicle is as thick as the hypocotyl, then tapering towards the growing point. It is ivory in colour. Lateral roots develop acropetally in four longitudinal rows, spreading in the surface layer of the soil.

As plant advance in age, the primary root increases in length and is mainly composed of a stout tap root. The lateral roots of successively higher order are developed, secondary, tertiary and so on. The lateral root usually bears nodulated outgrowth containing nitrogen fixing bacteria. The nodules are irregular, knobbly or globular in shape.

No measurements could be taken for the root system since it was difficult to obtain an intact root sample as the root was ruptured when pulled out of the soil.

**External morphology of the shoot system**

**Keen observations on shoot development:** The seedling stage came to an end at the age of 14 days, where plants averaged 11.4 cm in height.

As plants were 4 weeks old, 3 to 4 internodes were developed and a similar number of compound leaves were seen beside the prophylls. The first leaves to develop are the two prophylls, they are simple and oppositely arranged and still intact at this age. However, other foliage leaves (the true ones) are pinnately compound in alternative arrangement and trifoliate; i.e., leaflets three; with terminal petiolule longer than the laterals. The total leaf area per plant averaged 389.2 $cm^2$ and plants were some 27.3 cm in height.

When plants were 5 weeks old, the flowering stage started as flower buds developed.

At the age of 6 weeks, total internodes of the main stem are almost 6.0 in number and 22.4 cm long. Axillary buds on the main stem actively developed into secondary branches; about 5 lateral branches developed on the main stem at this age of plant development. Number of compound leaves per plant was about 20 and total leaf area averaged 2038.4 $cm^2$. The prophylls as well as the first and sometimes the second compound foliage leaves normally shrivel and defoliate. Opening of the flower buds started.

Figure 2 shows the habit of growth of kidney bean plant at the age of 8 weeks. The main stem reached its maximum length, being some 30.7 cm. The plant height, however, was about 58.7 cm. Number of internodes of the main stem averaged 7.3. Number of lateral branches ranged between 6 to 8. Leaves were about 28.3 in number. Total leaf area was some 2956.6 $cm^2$. The plant was in full blooming stage and some pods were developed.

At the age of 10 weeks, no more internodes, lateral branches and leaves developed. Fruits were completely developed (Fig. 3) and were harvest two weeks later.

Kidney bean is an annual herbaceous plant. The stem is erect, green in colour, ribbed, cylindrical and solid. Plant not more than 60 cm in height (determinate bush type). Stem nodes are few (6-8 in number). Branching starts at the second internode from the base then continuous upwards. Note worthy that, the lateral branches play a vital role in yield production. They are mainly responsible of flowering.

The aforementioned morphological description of the shoot is in accordance with that recorded by Rubatzky and Yamaguchi (1999) as well as by Decoteau (2000).

Fig. 2: A photograph of *Phaseolus vulgaris* L. plant at the age of eight weeks; plant reached its maximum height and secondary branches reached its maximum number; plant in full blooming stage and fruits start their formation

Fig. 3: A photograph of mature plant of *Phaseolus vulgaris* L., 10 weeks old, showing its habit of growth. Fruits were completely developed

**Morphology of vegetative growth**

**Plant height:** Results of plant height of kidney bean plant throughout the growing season are given in Table 1.

It is clear that the plant height increased consistently during the entire life span of the plant. The maximum height was reached at the age of 8 weeks, being 58.7 cm.

Table 1: The periodic growth and statistical parameters of plant height (cm) of *Phaseolus vulgaris* L. cv. Giza 6 throughout the growing season

| Plant age (weeks) | Range | Mean±SE |
|---|---|---|
| 2 | 9.9-14.5 | 11.4±0.70D |
| 4 | 23.5-29.2 | 27.3±0.82C |
| 6 | 36.3-44.6 | 40.6±1.28B |
| 8 | 53.8-63.5 | 58.7±1.45A |
| 10 | 52.1-60.7 | 56.3±1.39A |
| LSD (0.05) | | 4.26 cm |

Means having the same letter are not significantly different at 0.05 level

Table 2: The periodic growth and statistical parameters of main stem length (cm) of Phaseolus vulgaris L. cv. Giza 6 throughout the growing season

| Plant age (weeks) | Range | Mean±SE |
|---|---|---|
| 4 | 10.2-15.4 | 12.2±0.78C |
| 6 | 19.3-26.1 | 22.4±0.98B |
| 8 | 26.9-37.4 | 30.7±1.60A |
| 10 | 24.8-35.8 | 29.1±1.60A |
| LSD (0.05) | | 4.08 cm |

Means having the same letter are not significantly different at 0.05 level

No further increment was achieved. Elongation of plant continued at almost a uniform rate throughout the consecutive periods. However, the elongation rate of plant was much higher in the period from 6 to 8 weeks old. Through this period the plant height increased from 40.6 to 58.7 cm. Such increment (18.1 cm) represented 30.8% of the final plant height (58.7 cm).

**Length of the main stem:** Data pertaining to length of the main stem of Kidney bean plant throughout the growing season and the results of their statistical analysis are shown in Table 2.

Data of length of the main stem at successive ages proved that a significant increment in length occurred from the age of 4 weeks through the age of 8 weeks where the average length was 30.7 cm. This was statistically indifferent with the average length recorded at the age of 10 weeks (29.1 cm). Worthy to note that the period from 4 to 6 weeks old was the most active one throughout the entire growing season, since the length of the main stem increased from 12.2 to 22.4 cm i.e., 10.2 cm was added during these two weeks, being 33.2% of the final length of the main stem (30.7 cm).

**Number of internodes of the main stem:** Values in Table 3 show number of internodes of the main stem of kidney bean plant at successive ages of plant growth during the growing season.

It was found that number of internodes of the main stem averaged 3.67 at 4 weeks old. Such number increased significantly at the following sampling dates up to 8 weeks old reaching an average number of 7.33 internodes. No further significant increase in number of internodes of the main stem was recorded where the average number at the end of the growing season (10 weeks old) was 7.50 internode.

Table 3: The periodic growth and statistical parameters of number of internodes of the main stem of *Phaseolus vulgaris* L. cv. Giza 6 throughout the growing season

| Plant age (weeks) | Range | Mean±SE |
|---|---|---|
| 4 | 3-4 | 3.67±0.21C |
| 6 | 5-6 | 5.50±0.22B |
| 8 | 6-8 | 7.33±0.33A |
| 10 | 7-8 | 7.50±0.22A |
| LSD (0.05) | | 0.69 internode |

Means having the same letter are not significantly different at 0.05 level

Table 4: Length (cm) and diameter (mm) of successive internodes of the main stem of *Phaseolus vulgaris* L. cv. Giza 6 at the age of 10 weeks

| Characters | Range | Mean±SE |
|---|---|---|
| **Length (cm)** | | |
| First internode | 2.2-3.7 | 3.02±0.25 |
| Second" | 1.9-3.1 | 2.63±0.21 |
| Third" | 1.3-2.1 | 1.77±0.13 |
| Fourth" | 1.2-2.8 | 2.10±0.22 |
| Fifth" | 3.0-4.2 | 3.65±0.17 |
| Sixth" | 3.2-4.4 | 3.85±0.17 |
| Seventh" | 4.9-3.6 | 5.63±0.28 |
| Eighth" | 5.6-7.8 | 6.80±0.41 |
| **Diameter (mm)** | | |
| The basal internode | 9.0-12.0 | 10.50±0.50 |
| The median " | 5.0-7.0 | 6.30±0.33 |
| The apical " | 3.0-5.0 | 4.20±0.31 |

Table 5: The periodic growth and statistical parameters of number of secondary branches of *Phaseolus vulgaris* L. cv. Giza 6 throughout the growing season

| Plant age (weeks) | Range | Mean±SE |
|---|---|---|
| 4 | 2-3 | 2.33±0.21C |
| 6 | 4-5 | 4.50±0.22B |
| 8 | 6-8 | 7.17±0.31A |
| 10 | 7-8 | 7.33±0.21A |
| LSD (0.05) | | 0.71 branch |

Means having the same letter are not significantly different at 0.05 level

**Length and diameter of successive internodes of the main stem:** Results in Table 4 represent range and average of length and diameter of successive internodes of the main stem of Kidney bean plant 10 weeks old.

The average length of the first internodes of the main stem was 3.02 cm. Average length of successive internodes decreased reaching 1.77 cm for the third internode. Average length of internodes then increased gradually up to the eighth internode reaching 6.80 cm.

In respect of the main stem diameter, internodes were relatively thick at base and tapering towards the top, being 10.5, 6.3 and 4.2 mm in diameter for internodes number 1, 5 and 8; respectively.

**Number of secondary branches:** Values belonging to number of secondary branches of kidney bean plant during the growing season and their statistical analysis are given in Table 5.

Up to the age of 4 weeks, Kidney bean plant formed 2.33 secondary branches. This number was almost doubled throughout the following 2 weeks recording 4.50 secondary branches. The next sample the age of

Table 6: Range and average of length of secondary branches (cm) of *Phaseolus vulgaris* L. cv. Giza 6 at the age of 10 weeks

| Branch number (from base) | Range | Mean±SE |
|---|---|---|
| First | 44.5-55.5 | 49.7±1.54 |
| Second | 44.5-53.0 | 49.3±1.23 |
| Third | 31.0-43.5 | 38.3±1.81 |
| Fourth | 26.5-35.0 | 31.9±1.28 |
| Fifth | 19.5-31.5 | 25.8±1.89 |
| Sixth | 19.0-31.0 | 25.0±1.95 |
| Seventh | 18.0-26.5 | 21.8±1.43 |
| Eighth | 16.0-24.0 | 20.9±1.52 |

Table 7: The periodic growth and statistical parameters of fresh weight of leafless shoot (g) / plant of *Phaseolus vulgaris* L. cv. Giza 6 throughout the growing season

| Plant age (weeks) | Range | Mean±SE |
|---|---|---|
| 2 | 1.75-2.38 | 1.96±0.10D |
| 4 | 7.78-9.84 | 8.81±0.39C |
| 6 | 34.83-47.51 | 41.39±1.81B |
| 8 | 77.84-99.63 | 89.28±3.01A |
| 10 | 72.92-94.16 | 83.72±2.99A |
| $LSD_{(0.05)}$ | | 6.04 g |

Means having the same letter are not significantly different at 0.05 level

8 weeks showed significant increase and recording a number of 7.17 secondary branches. No substantial increment was achieved after this sampling date. The lateral shoot played a main role in bearing the inflorescences.

**Length of secondary branches:** Data pertaining to range and length of secondary branches of kidney bean plant toward the end of growing season (10 weeks old) are presented in Table 6.

Lateral shoots of kidney bean plant developed in an acropetal succession i.e., from the base toward the apex. The first branch, the lowest one, averaged 49.7 cm and ranged from 44.5-55.5 cm. The average length of secondary branches then decreased reaching a minimum of 20.9 cm for the uppermost one, eighth branch which ranged from 16.0 to 24.0 cm.

**Fresh weight of leafless shoot:** Results of fresh weight of the leafless shoot of Kidney bean plant throughout the growing season and their statistical analysis are represented in Table 7.

Average fresh weight of leafless shoot was 1.96 g at 2 weeks old. Thereafter, a significant increase in such weight was achieved reaching a maximum of 89.28 g when plants were 8 weeks old. At this age plant attained its final height, maximum number of lateral branches and was in full blooming stage and some pods were completely developed.

**Dry weight of leafless shoot:** Results of dry weight of the leafless shoot of Kidney bean plant throughout the growing season and their statistical analysis are given in Table 8. No significant increment was recorded in dry weight of the leafless shoot up to the age of 4 weeks, being 1.12 g. Average weight of leafless shoot, thereafter, increased significantly and gradually during the following periods reaching a maximum of 16.04 g at 8 weeks old.

Table 8: The periodic growth and statistical parameters of dry weight of leafless shoot (g)/plant of *Phaseolus vulgaris* L. cv. Giza 6 of throughout the growing season

| Plant age (weeks) | Range | Mean±SE |
|---|---|---|
| 2 | 0.16-0.22 | 0.19±0.01C |
| 4 | 0.84-1.39 | 1.12±0.10C |
| 6 | 6.94-8.48 | 7.87±0.23B |
| 8 | 13.69-17.14 | 16.04±0.53A |
| 10 | 13.17-16.68 | 15.53±0.53A |
| $LSD_{(0.05)}$ | | 1.03 g |

Means having the same letter are not significantly different at 0.05 level

Table 9: The periodic growth and statistical parameters of total number of leaves per plant of *Phaseolus vulgaris* L. cv. Giza 6 throughout the growing season

| Plant age (week) | Range | Mean±SE |
|---|---|---|
| 2 | 2-3 | 2.17±0.17D |
| 4 | 6-7 | 6.67±0.21C |
| 6 | 18-24 | 20.17±0.91B |
| 8 | 24-31 | 28.33±0.99A |
| 10 | 23-29 | 26.83±0.87A |
| $LSD_{(0.05)}$ | | 2.35 leaves |

Means having the same letter are not significantly different at 0.05 level

Table 10: The periodic growth and statistical parameters of total leaf area per plant ($cm^2$) of *Phaseolus vulgaris* L. cv. Giza 6 throughout the growing season

| Plant age (week) | Range | Mean±SE |
|---|---|---|
| 2 | 43.4-55.8 | 50.38±2.03E |
| 4 | 347.2-413.6 | 389.15±11.47D |
| 6 | 1828.4-2208.2 | 2038.43±60.79C |
| 8 | 2744.5-3126.8 | 2956.63±60.02A |
| 10 | 2453.6- 2998.4 | 2704.73±79.16B |
| $L.S.D_{(0.05)}$ | | 192.48 $cm^2$ |

No increment was recorded after this sampling date. Worthy to note that dry weight of leafless shoot increased noticeably during the period of 6 to 8 weeks old, where weight increased from7.87 to 16.04 g; i.e., 8.17 g was added during these 2 weeks, being 50.9% of the maximum dry weight of the leafless shoot.

**Number of leaves per plant:** Data pertaining to number of leaves per plant of Kidney bean throughout the growing season and their statistical analysis are represented in Table 9.

It is evident that a significant increment in number of leaves per Kidney bean plant was achieved till the age of 8 weeks, reaching 28.33. At the age of 10 weeks the recorded number of leaves per plant was 26.83, being indifferent with the previous sampling date. Such decrease was due to normal defoliation associated with aging.

**Total leaf area per plant:** Results of total leaf area per Kidney bean plant throughout the growing season and their statistical analysis are given in Table 10.

Table 11: The periodic growth and statistical parameters of fresh weight of leaves (g) per plant of *Phaseolus vulgaris* L. cv. Giza 6 of throughout the growing season

| Plant age (weeks) | Range | Mean±SE |
|---|---|---|
| 4 | 7.53-12.35 | 10.20±0.82D |
| 6 | 34.25-44.87 | 40.02±1.76C |
| 8 | 47.31-63.18 | 57.29±2.46A |
| 10 | 44.94-57.42 | 51.21±2.12B |
| $LSD_{(0.05)}$ | | 5.58 g |

Table 12: The periodic growth and statistical parameters of dry weight of leaves (g) per plant of *Phaseolus vulgaris* L. cv. Giza 6 throughout the growing season

| Plant age (weeks) | Range | Mean±SE |
|---|---|---|
| 4 | 1.55-2.41 | 1.98±0.15D |
| 6 | 6.84-8.75 | 7.92±0.33C |
| 8 | 10.92-16.35 | 14.03±0.77A |
| 10 | 9.85-14.47 | 12.35±0.64B |
| $LSD_{(0.05)}$ | | 1.57 g |

It is realized from Table 10 that total leaf area per Kidney bean plant showed a steady significant increase till the age of 8 weeks, reaching its maximum recording an average of 2956.6 $cm^2$. Then the area showed a significant decline towards the end of the growing season reaching 2704.7 $cm^2$ at the age of 10 weeks due to normal abscission of basal leaves.

**Fresh weight of leaves per plant:** Data pertaining to fresh weight of leaves per Kidney bean plant throughout the growing season and their statistical analysis are presented in Table 11.

It is clear from Table 11 that up to 4 weeks old, average fresh weight of leaves per plant was 10.2 g. A gradual significant increase occurred thereafter reaching 57.29 g when plants aged 8 weeks. Then the weight showed a significant decline towards the end of the growing season reaching 51.21 g at the age of 10 weeks due to normal shrivel and abscission of basal leaves.

**Dry weight of leaves per plant:** Results of dry weight of leaves per kidney bean plant during the growing season and their statistical analysis are given in Table 12.

It is noted from Table 12 that the growth pattern of dry weight of leaves per plant showed the same trend of their fresh weight given earlier. Average dry weight of leaves per plant was 1.98 g at 4 weeks old. A steady significant increase occurred thereafter reaching 14.03 g when plants aged 8 weeks. Then the dry weight of leaves decreased, being 12.35 g at the age of 10 weeks.

**Descriptive morphology of the leaves:** Kidney bean plant bears two types of leaves:

**Simple leaf:** The first two basal leaves, prophylls (Fig. 1) are simple, oppositely arranged, green in colour, cordate in shape, with entire margin, 2 cm long and 1.5 cm broad, long petiolated, reticulate pinnate venation and the midrib divides the blade into two equal parts. The two prophylls defoliate when plants aged 6 weeks.

**Compound leaf:** Leaves other than the first two basal prophylls are compound, where the leaf is divided into leaflets. Leaf is trifoliate i.e., leaflets three, pinnately compound with the terminal petiolule longer than the two lateral ones (Fig. 4 and 5). Leaves are alternate, green in colour. Leaflets are ovate in shape, rounded at the base, pointed at the apex and with entire margin. The leaves (blades and petioles) are covered with short hairs. Venation is reticulate-pinnate. The midrib divides the blade of the apical leaflet into two equal sides, but the lateral ones are unequal-sided. The leaf has two small stipules at its base. The apical leaflet has two small stipels and each of the lateral ones has only one stipel.

The aforementioned morphological description of the compound leaf is in accordance with that recorded by Purseglove (1988) and by Decoteau (2000).

**Morphology of reproductive growth**

**The inflorescence and the flower:** Formation of inflorescences in Kidney bean plant starts at the age of 5 weeks in form of flower buds. The inflorescence developed on both the main stem and the lateral branches. A week later, opening of the flower buds started and anthesis takes place. At the age of 8 weeks, full blooming and start of fruit formation occur. When plants are 10 weeks old all flowers develop into fruits and fruits are completely matured and ready for harvest two weeks later.

Inflorescence (Fig. 5) is an axillary raceme bearing few flowers (2-3); lax racemes, usually shorter than leaves, with flowers at or near apex of peduncle.

Flower of Kidney bean plant (Figures 5 and 6) is zygomorphic, bisexual, perigenous and white in colour. The flower has a short pedicel with two broad-ovate leafy bracts. Calyx-bracts nearly equalling or exceeding calyx tube. Calyx is green in colour, tubular, hairy and gamosepalous. Corolla is white in colour, typically papilionaceous with 5 petales being descending imbricate, the posterior petal is outermost (standard or vaxillum), the two lateral petals with long claw (wings) and the two anterior united petals (keel). The keel is somewhat coiled. Stamens are enclosed within the keel, diadelphous (9), 1, the posterior stamen is free and filaments of the rest nine are fused to form a tube like structure. Gynoecium is comprised of one carpel. The ovary is superior, elongated, green in colour and unilocular. Ovules numerous and placentation is marginal. Style is long, bent at its base and terminates with the stigma.

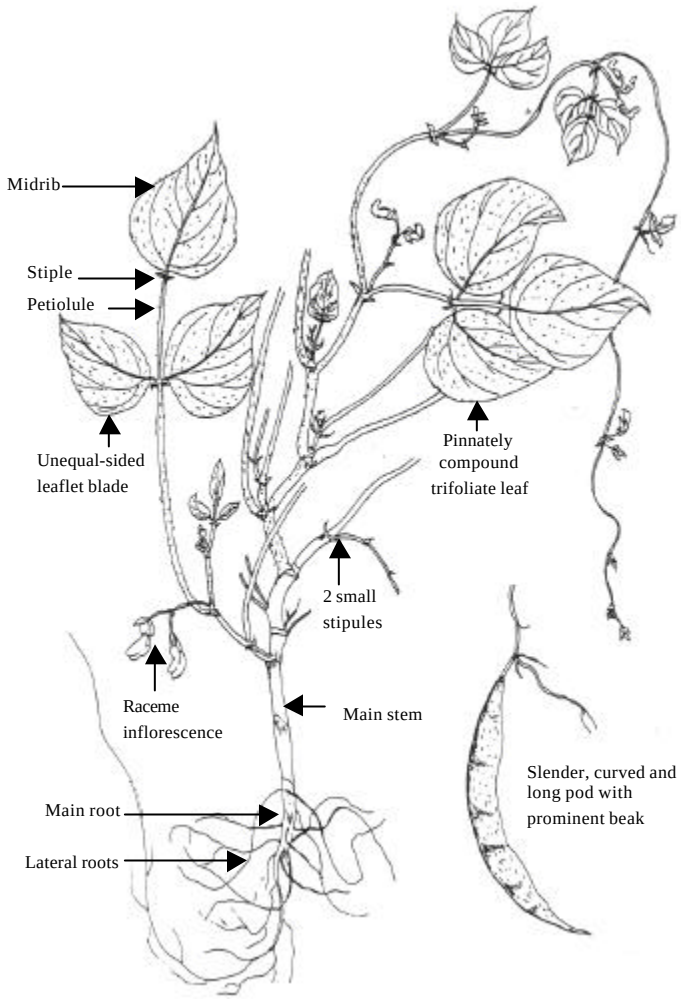


Fig. 4: Schematic representation of *Phaseolus vulgaris* L. plant, 8 weeks old, showing vegetative and reproductive structures

The floral formula for Kidney bean plant is as follows: %, ♀, $CA_{(5)}$, $CO_{1, 2, (2)}$, $A_{(9)}$, 1, $G_1$ Marginal placentation.

**The fruit and the seed:** Fruit of kidney bean plant (Fig. 7) is green in colour and turned into yellow brown when matured. It is simple dehiscent legume (pod), splitting along both sutures at maturity. Pod slender, curved or somewhat straight, long, about 13 cm in length with prominent beak, narrower, about 0.8-1.0 cm in width, usually 4-5 seeded and glabrous.

Seeds (Fig. 8) are white in colour, relatively large in size, kidney in shape and hilum usually white. Seed length about 1.6 cm, breadth about 0.7 cm and thickness about 0.6 cm. Embryo is relatively large and dicotyledonous. Endosperm is absent.

Table 13: The periodic growth and statistical parameters of fresh weight of reproductive organs (g) per plant of *Phaseolus vulgaris* L. cv. Giza 6 throughout the growing season

| Plant age (weeks) | Range | Mean±SE |
|---|---|---|
| 6 | 18.36-28.69 | 21.70±1.47C |
| 8 | 72.86-91.18 | 82.40±2.99B |
| 10 | 94.68-114.37 | 103.17±3.03A |
| $LSD_{(0.05)}$ | | 7.84 g |

The aforementioned description of fruit and seed is in harmony with that given by Purseglove (1988).

**Fresh weight of reproductive organs:** Data of fresh weight of reproductive organs of Kidney bean plant throughout the growing season and their statistical analysis are shown in Table 13.


Fig. 5: (a) A photograph showing compound leaf and reproductive organs (the inflorescence and the flower) of *Phaseolus vulgaris* L. (b-d) A photograph of *Phaseolus vulgaris* L. flower, showing its different whorls, (b) Corolla of 1 standard petal, 2 lateral wing petals with long claw and 2 keel petals, (c) Flower after removing the corolla. Notice the diadelphous tube like androecium. The diadelphous androecium with (9) and 1 stamens, the anthers are free and (d) Gynoecium showing superior ovary of 1 carple

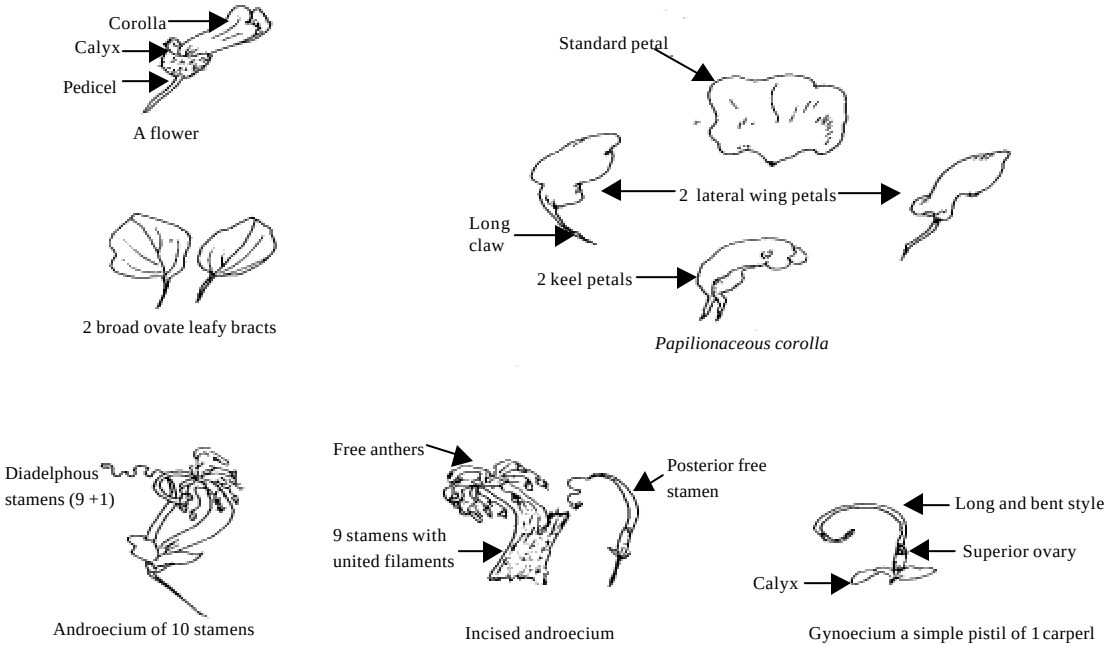


Fig. 6: Schematic representation of *Phaseolus vulgaris* L. flower

At the age of 6 weeks, average fresh weight of reproductive organs per plant was 21.7 g. A significant enhancement in this weight was recorded in the following period reaching 82.4 g when plants aged 8 weeks. At the

Fig. 7: A photograph of *Phaseolus vulgaris* L. fruits. Plants are 10 weeks old. Note that legume is glabrous, still green in colour, slender, curved or somewhat straight, long with prominent beak and constricted between the seeds

Fig. 8: A photograph of *Phaseolus vulgaris* L. seeds from plants aged 12 weeks

age of 10 weeks, another substantial increase in fresh weight of reproductive organs was attained, the weight reaching its maximum being 103.17 g.

**Dry weight of reproductive organs:** Results of dry weight of reproductive organs of kidney bean plant throughout the growing season and their statistical analysis are given in Table 14.

Worthy to note that the growth pattern of dry weight of reproductive organs per Kidney bean plant followed an identical manner to that of their fresh weight given earlier. At the age of 6 weeks, average dry weight of reproductive organs per plant was 2.81 g. Values obtained periodically increased significantly towards the end of growing season, being 39.36 g at the age of 10 weeks.

Table 14: The periodic growth and statistical parameters of dry weight of reproductive organs (g) per plant of *Phaseolus vulgaris* L. cv. Giza 6 throughout the growing season

| Plant age (weeks) | Range | Mean±SE |
|---|---|---|
| 6 | 2.28-3.61 | 2.81±0.25C |
| 8 | 25.58-33.14 | 29.55±1.10B |
| 10 | 34.16-45.26 | 39.36±1.59A |
| $LSD_{(0.05)}$ | | 3.39 g |

Table 15: Yield components of *Phaseolus vulgaris* L. cv. Giza 6 plant at harvest time (the age of 11 weeks)

| Yield characters | Range | Mean±SE |
|---|---|---|
| Number of pods per plant | 25-33 | 28.70±1.95 |
| Weight of pods per plant (g) | 42.11-64.16 | 56.82±2.77 |
| Number of seeds per pod | 4.1-4.3 | 4.20±0.04 |
| Number of seeds per plant | 97-135 | 120.70±5.13 |
| Yield of seeds per plant (g) | 32.29-46.11 | 40.56±2.68 |
| Weight of 100 seeds (g) | 32.26-34.48 | 33.59±0.37 |

**Yield components:** Results of yield components of Kidney bean plant at harvest time are given in Table 15.

Average number of pods per plant was 28.7 and their weight was 56.82 g. At the same time, average number of seeds per pod was 4.2. Whereas, average number of seeds per plant was 120.7 which weight 40.56 g. In the meantime, the specific weight of seeds (average weight of 100 seeds) was 33.59 g.

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