

Crotalaria Juncea L. Plant Ontogenetic Developmental Stages

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Abstract *Crotalaria juncea* L. (Fabaceae), commonly known as Sunnī kenewer, is a thermophilic annual species adapted to the saline loamy alluvial soils of the Khorezm region. This study investigated the stages of ontogenesis, germination capacity, seasonal phenology, and morphological development of the species under local agroecological conditions from 2020 to 2024. Laboratory germination tests demonstrated that seeds stored for one year exhibit 90–100% germination at 20–24 °C, while germination efficiency decreases significantly at lower temperatures. Field experiments revealed that sowing in late April–early May ensures optimal emergence, with seedlings appearing within 3–5 days when seeds are pre-soaked for 6–8 hours. The vegetative phase lasts 10–15 days, followed by rapid shoot and leaf development leading to flowering 30–40 days after sowing. The plant reaches 160–180 cm at full maturity, forming multiple branching levels and producing pods containing 2–12 seeds. The total vegetation period under Khorezm conditions lasts 150–190 days as a main crop and 130–150 days when cultivated as a secondary crop, the latter resulting in a 50–70% reduction in seed yield. When mixed at 15–30% with forage crops, *Crotalaria juncea* significantly increases hay biomass and is also valuable as a nectar resource for beekeeping. These results indicate strong ecological adaptability and agricultural potential of *Crotalaria juncea* for improving forage quality and expanding sustainable agroecosystems in arid regions.

Keywords *Crotalaria juncea* L., Ontogenesis, Seed germination, Phenology, Forage crop, Khorezm region, Saline soils, Biomass productivity, Leguminous plants, Agroecological adaptation

1. Introduction

Crotalaria juncea L., a member of the Fabaceae family, also known as rattlepod, Indian hemp, Madras hemp, or Sunnī kenewer, is a plant adapted to the (saline) loamy alluvial soils of Khorezm Province. It has been studied for improving the productivity of degraded and marginal soils, for increasing above-ground biomass as forage for wheat and other forage crops by mixing 10–30% into the crop, for expanding apiculture due to nectar-rich flowers, and for use in pharmaceutical and ecological applications.

2. Materials and Methods

To study the bioecological properties of plants during ontogenesis, methods of T.A. Rabotnov [8] and I.G. Serebryakov [6] were employed. For assessing seed germination under

laboratory conditions, 100 seeds were placed on moistened filter paper in Petri dishes with distilled water and incubated at room temperature. For field germination and seedling survival, in spring (late April) 100 seeds were sown in rows at depths of 3–4–5 cm in prepared soil, with four replications. To determine sowing rate, experiments used 15–20 seeds per meter. To evaluate the effect of sowing date on germination, seeds were sown at the end of April and early May.

The seasonal development trajectory, i.e., ecological and phenological observations and phenological spectra, were studied using the methods of I.V. Borisova [3] and I.N. Beydeman [4]. During the growing season, the plant's tillering, appearance of true leaves, shoot formation, tillering, onset of flowering, completion of flowering, pod formation, seed filling, seed maturation, and duration of vegetation were examined. Morphological indicators at different stages were obtained from model plants in the experimental field; results are presented as means from 25 plants. Crop yield was determined on a flat area of 1 m² and on a designated plot corresponding to 1 plant per meter.

3. Results

The growth and development of *Crotalaria juncea* and its adaptability to diverse ecological conditions were studied, and specific characteristics were identified. The fruit of *Crotalaria juncea* is a pod; the seeds are lens-shaped, small to large, black and gray in color, occasionally green, with length 0.5–1.0 mm and width 0.4–0.5 mm. The weight of 1000 seeds is 39–42 g. In laboratory conditions, seed germination at 20–24 °C reaches 90–100% within 2–3 days. The viability of seeds stored for one year at 16–18 °C was 55.4% (Table 1).

Table 1. Seed Germination Rate of *Crotalaria juncea* under Laboratory Conditions, %

Temperature, °C	Storage Duration, years				
	1	2	3	4	5
10-14	2,9	2,4	2,2	1,2	0,0
16-18	55,4	52,1	48,2	43,3	40,0
20-24	100,0	100,0	98,2	96,1	94,0
29-33	100,0	100,0	99,1	97,3	96,6

Seed germination is strongly influenced by temperature, a key factor determining the plant's propagation and seed quality. The literature (Terexin [7], Askochenskaya, M.G. Nikolaeva (1982), M.G. Nikolaeva *et al.*, J.D. Bewley, M. Brack [2], G.T. Djamalova, A. Seitkarimov [5]) reports that many legumes germinate well at higher temperatures. In the laboratory, seeds stored for 1–2 years did not germinate below 10 °C; however, when soil temperature rose to around 20 °C in late April–early May and air temperature reached 29–33 °C, 99–100% germination occurred, indicating that *Crotalaria juncea* germinates well at higher temperatures.

Seed germination in the laboratory, following the recommendations of R.T. Tojiev and A.S. Hamidov [9], involves soaking seeds in plain water for 6–8 hours and placing them on moist filter paper in sterile Petri dishes; after one day, seeds germinate and seedlings with 0.6–0.9 mm radicles appear. Water is essential for seed germination. After two days, two cotyledons formed, with lengths of 0.8–1.0 cm and widths of 0.3–0.5 cm; seedling height reached 3–4 cm. Three days later, two lanceolate leaves appeared, with average length around 1.3 cm and width ~0.6 mm. The hypocotyl length reached 8 cm, and the root length was 3–5 cm. Five days later, the hypocotyl stood 10–13 cm tall, with leaf size around 3.0 × 0.8–1.0 cm.

In Khorezm region loamy alluvial soils, from 2020–2024, seed germination of 80–94% was observed for *Crotalaria juncea* seeds with varying salinity. *Crotalaria* species are tropical-region herbs, either annual or perennial, with about 700 species [1]. When cultivated as a primary or secondary crop, sowing at the end of April initiates flowering after 30–40 days; initial pods mature by late September to early October, and the plant may flower again in November like wheat, but flowers may shed or not mature by November; germination in November is relatively low.

Virginile phase. Seedling stage. *Crotalaria juncea* is a thermophilic plant. Based on Khorezm regional soil-climate

conditions, seeds were sown as a main crop (25.04–5.05) and as a secondary crop after autumn wheat (10.06–15.06). A soil temperature of 18–25 °C is required for these sowings. In experiments, soaking seeds in plain water for 6–8 hours yielded complete germination in 3–5 days. Five-day-old seedlings had green cotyledons, with length 0.6–1.5 cm and width 0.3–0.5 cm; plant height was 0.5–1 cm. The primary root began to grow slowly from the first day. The vegetative phase is very short, lasting 10–15 days, ending with a seedling depth of 3–4 cm. **Juvenile phase.** By May 10, plant height is 5–7 cm; cotyledon leaves enlarge to 2–3 × 0.5–0.7 cm, and the first and second true leaves begin to form. True leaves are green and lanceolate. Roots reach 5–6 cm with several lateral roots. The number and size of leaves increase daily. By May 15, each plant has 6 leaves. A new leaf forms every 4–5 days. Leaves are sessile and alternately arranged. By this stage, leaf size is 1.5–2 × 0.4–0.6 cm. After about a week (20–25.05), plant height is 12–14 cm with 8–12 leaves. End of vegetative phase. Leaves are flat, narrowly linear to elliptical, small-pubescent, softly felted on both sides, silver-tomentose, 4–13 cm long and 0.5–3 cm wide, arranged alternately along the stem. Upper leaves measure 5–8 × 0.6–2 cm, middle leaves 8–10 × 1.5–2.5 cm, lower leaves 7–8 × 1.5 cm. Leaves remain green through the vegetative phase; by late October to early November, lower nodes' leaves turn pale green and then yellow, dying from the bottom up. *Crotalaria juncea* begins flowering about 30 days after sowing; by late May to early June, rapid growth and development are observed. The plant remains in a mature virginile state without premature maturation. Average air temperature at this time is about 20–25 °C. Plant height reaches 25–35 cm. The root is a tap root, penetrating 6–10 cm with further development of numerous finer roots. By early June, when air temperature is around 30 °C, a mature virginil plant with a main stem length of 35–45 cm is observed; root depth at the beginning of the vegetative period is 10–15 cm, at the end 20–35 cm; second-order laterals 17–25 cm; third-order 10–15 cm. Symbiotic bacteria of the *Rhizobium* lineage (*Mesorhizobium* and *Bradyrhizobium* spp.) are found on the surrounding root zone and fine root hairs. **Generative and pod-filling phase.** Under Khorezm province's soil-climate conditions, after sowing *Crotalaria juncea*, the flowering phase begins 30–40 days later, depending on weather, by the first week of June, with 5–10% of plants flowering early. The plant begins flowering from the main stem, with flowers appearing on the lower parts of the lateral branches—namely, the first-, second-, third-, and fourth-order shoots. The pods are covered with fine hairs and consist of a single carpel. When mature, the seeds are light brown in color. The pods measure 3–6 cm in length and 1–2 cm in diameter, with each pod containing from 2 to 12 seeds. The generative organs of *Crotalaria juncea* constitute 50–80% of the total plant biomass. The overall plant height ranges from 160 to 180 cm, with four levels of branching: first-order branches measuring 80–130 cm, second-order 60–120 cm, third-order 40–60 cm, and fourth-order 20–30 cm. The flowering period begins at the end of May and

continues until November, during which pods form and remain attached to the plant stem—indicating the absence of pod shattering (i.e., the species does not exhibit dehiscence). The ripening of the pods depends on climatic and weather conditions.

4. Conclusions

Under the soil and climatic conditions of the Khorezm region, the ontogenetic period of *Crotalaria juncea* L. as a main crop lasts 150–190 days. The total vegetation period, depending on weather conditions, begins in late April and continues until early or mid-November. When cultivated as a secondary crop for seed production, the growth period is 130–150 days, and seed yield is 50–70% lower compared to the main crop. The hay yield, when mixed with other forage crops (15–30%), demonstrates significant importance for livestock feeding.

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