Mini Review

Hardinath Hybrid-1: First Nepalese Hybrid Rice to Strengthen Rice Production and Food Security

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ABSTRACT

Rice is the cornerstone of Nepal's agricultural sector, both in terms of production and land area dedicated to its cultivation. However, with a population growth rate of 2.25%, current rice production and productivity are insufficient to meet the increasing demand in the coming years. Since expanding the cultivated area is no longer a viable solution, enhancing rice yield is the only feasible path forward. To address this challenge, increasing yield potential is essential. In line with this, the National Seed Vision 2013–2025 emphasis the importance of hybrid rice, setting a target to release at least eight hybrid varieties by 2025. In response to this national goal, the Nepal Agricultural Research Council has released Hardinath Hybrid-1, Nepal's first-ever hybrid rice variety. This hybrid rice is characterized by high yielding with fine grain and medium maturity which fits in rice-vegetable cropping system. This development paves the way for improved rice production and greater food security for the nation.

KEYWORDS: rice, hybrid; National Seed Vision; Hardinath Hybrid-1

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BACKGROUND

Rice remains the staple food for over 95% of Nepal's population and is cultivated across the largest area—1.45 million hectares-with a productivity of 3.8 t ha^{-1} [1]. However, its cultivation is predominantly dependent on the monsoon season, making it highly susceptible to fluctuations in rainfall and the impacts of climate change. Only 49% of the rice-growing area is irrigated, with the rest relies on seasonal monsoon rainfall. Given the population growth rate of 2.25%, current rice production and productivity will not be sufficient to meet the growing demand in the coming years. Since expanding the cultivated area is not a

viable option, increasing both rice production and productivity is crucial to addressing this challenge.

Studies indicated that the estimated demand for rice can be met by increasing current production by at least 27%–43% by 2030 and 42%–85% by 2050 under different scenarios [2]. Tripathi et al. [3] reported that rice yield must increase from the current 3.8 t ha^{-1} by 2035, assuming the cultivated area remains unchanged. To achieve this, various intensive measure must be implemented. Timsina et al. [2] highlighted the need to expand the coverage of hybrid rice from current 10% to 25% by 2030 by increasing the area under spring rice cultivation and introducing hybrid technology in stress-prone areas, targeting and average productivity of at least 6.5 t ha^{-1}.

Hybrid rice has the potential to yield 15%–20% more than inbred varieties [4]. In China, hybrid rice cultivation has demonstrated a 20%–30% yield advantage compared to high-yielding inbred rice varieties [5]. Currently, more than 17 countries are actively involved in hybrid rice development. While labor costs for cultivating hybrid rice are similar to those of inbred varieties, hybrid rice requires higher seed and input costs. However, the increased yield from hybrid varieties allows farmers to meet their household consumption needs and sell surplus produce at competitive market prices.

The Nepalese government has registered 65 multinational hybrid rice varieties, primarily sourced from India, China, and other countries. However, only a limited number of these varieties have gained popularity. Most of the registered hybrid varieties are approved for cultivation in the terai and Inner terai regions, up to 700 meters above sea level, despite the growing demand for hybrid rice in the mid-hills, valleys, and Terai regions. The National Seed Vision 2013–2025 also emphasizes the need for hybrid rice, setting a target to release at least eight hybrid varieties by 2025. In line with this national objective, the Nepal Agricultural Research Council has released Hardinath Hybrid-1, Nepal's first officially released hybrid rice variety.

Hardinath Hybrid-1 is a high yielding, semi-dwarf hybrid rice variety that matures early (115–125 days) and is well-suited for double-rice and rice-vegetable systems, which dominate the mid hills, valley, and Inner Terai regions. It is a three-line system hybrid, comprising an A-line (Cytoplasmic male sterile (CMS line), B-line (maintainer line), and R-line (restorer line). This article describes the development of Hardinath Hybrid-1 and its major characteristics.

Hybrid Variety Development Initiation

The first CMS-based heterosis breeding in rice in Nepal was reported by Joshi in 2003 A.D. in his Master's thesis. Hybrid rice research was introduced in Nepal in 2002 A.D. with the initiation of the International Rice Hybrid Observation Nursery (IRHON) by International Rice Research Institute (IRRI). However, the sharing of hybrid observation nursery

materials was halted when Nepal did not hold membership in the Hybrid Rice Development Consortium (HRDC). In 2011 A.D., after Nepal was granted HRDC membership, the exchange of hybrid (F1) germplasm resumed. This led to the evaluation of 25 F1 hybrid rice varieties at the National Rice Research Program in Hardinath, Dhanusha. Among the 25 rice hybrids, the top three highest-yielding hybrids were selected and parental lines were requested from HRDC, IRRI. Two of these three requested hybrids, both utilizing the three-line system, were chosen to initiate hybrid rice varietal development in Nepal starting in 2013 A.D. The CMS line maintenance and F1 seed production were carried out, and after successfully synchronizing the male and female flowers, large-scale production of F1 seeds was conducted. As a result, two hybrids—Hardinath Hybrid-1 and Hardinath Hybrid-3—were successfully released in 2019 A.D. Five metric tons of F1 seed of Hardinath Hybrid-1 were produced and disseminated in collaboration with a private seed company. In 2014 A.D., 15 hybrid parent lines were brought from HRDC, IRRI, and research efforts continue to develop additional national hybrid varieties.

Major Characteristics and Key Traits of Hardinath Hybrid-1 and its Parents

Hardinath Hybrid-1 is a semi-dwarf, short-duration crop, with an average plant height ranging from 99 to 113 cm. its growth duration of 112–121 days in the rainy season and 120–129 days in the spring season (Table 1). This variety stands out for its high yield, particularly when compared to other early-maturing rice varieties released in Nepal. It is classified as a high-tillering hybrid, in contrast to the “New Plant Type” varieties, which have lower tillering but larger tillers and panicles [6].

Table 1. Major characteristics and key traits of Hardinath Hybrid-1.

SN	Characters	Hardinath hybrid-1
1	Panicle length (cm)	28.4
2	Number of effective tillers/hill	11–12
3	Number of total tillers/hills	14–16
4	Days to flowering (from seeding)	80–104
5	Days to maturity (from seeding)	112–129
6	Plant height (cm)	99–113
7	Grain yield (t ha^{-1})	6.5–8.2
8	1000 grain weight (g)	23.0–24.9

Grain Quality and Economically Important Traits of Hardinath Hybrid-1

Hardinath Hybrid-1 grains have an attractive physical appearance, characterized by their long, slender shape. This variety has moderate amylose content and a balanced gelatinization temperature (Table 2), both of which are important for achieving the ideal texture of cooked rice, particularly for consumers in Southeast Asia. The grain length, breadth and grain length-to-breadth ratio refer to the unhulled grain, and the rice length, breadth, and rice length-to-breadth ratio refer to hulled rice (Table 3). The grain length of Hardinath Hybrid-1 is 7.2 mm, with a grain breadth of 1.6 mm, resulting in a length-to-breadth ratio of 4.3 (Table 3). This ratio is notably higher than that of other popular rice varieties, such as Khumal-4 [7], Sabitri, and Swarna.

Table 2. Processing and nutritional quality of Hardinath Hybrid-1 rice hybrid variety.

SN	Parameters	Hardinath Hybrid-1 (HH1)
1	Brown rice	74.3%
2	Total milled rice	56.8%
3	Head rice	52.5%
4	Total ash	2.03%
5	Bulk density	50.6 g/cm^3
6	Crude fiber	1.3%
7	Fat	1.2%
8	Carbohydrate	76.7%
9	Protein	6.1%
10	Amylose	Medium
11	Gelatinization Temperature	Medium
12	Phosphorus (mg)	220.4
13	Iron (mg/100 g)	0.61
14	Calcium (mg/100 g)	71.1

Table 3. Physical measurement of rice grain of Hardinath Hybrid-1 and its parents.

Parameters	Female	Male	Hardinath Hybrid-1
Grain Length (mm)	9.9	10.6	10.5
Grain Breadth (mm)	1.84	2.02	1.94
Grain L:B ratio	5.4	5.2	5.4
Rice Length (mm)	6.70	7.40	7.24
Rice Breadth (mm)	1.61	1.76	1.68
Rice L:B ratio	4.1	4.2	4.3

Morphological and DUS Characters of Hardinath Hybrid-1

The morphological characterization of the Hardinath Hybrid-1 rice hybrid variety was conducted at the National Rice Research Program in Hardinath, Dhanusa. The major identifying characteristics include a green basal leaf with an erect culm, and in late observation, flag leaves were erect. Colorless auricles present with split-shaped white ligules and white stigma. The auricles are colorless, with a split-shaped white ligule and white stigma. A very short awn is present at the tip, which appears yellowish-white in later stages. The morphological characteristics of hybrid rice variety Hardinath Hybrid-1 is given below (Table 4).

Table 4. Morphological characteristics of hybrid rice variety Hardinath Hybrid-1.

Characters	States	Hardinath Hybrid-1
Basal leaf: leaf color	Green (1) / Light purple (2) / Purple lines (3) / Uniform purple (4)	Green (1)
Leaf: intensity of green color	Light (3) / Medium (5) / Dark (7)	Medium (5)
Leaf: anthocyanin coloration	Absent (1) / Present (9)	Absent (1)
Leaf-sheath: anthocyanin coloration	Absent (1) / Present (9)	Absent (1)
Leaf: pubescence of blade surface	Absent (1) / Weak (3) / Medium (5) / Strong (7) / Very strong (9)	Absent (1)
Leaf: auricles	Absent (1) / Present (9)	Present (9)
Leaf: anthocyanin colouration of auricles	Colorless (1) / Light purple (2) / Purple (3)	Colorless (1)
Leaf: collar	Absent (1) / Present (9)	Present (9)
Leaf: anthocyanin coloration of the collar	Absent (1) / Present (9)	Absent (1)
Leaf: ligule	Absent (1) / Present (9)	Present (9)
Leaf: shape of ligule	Truncate (1) / Acute (2) / Split (3)	Split (3)
Leaf: colour of ligule	White (1) / Light purple (2) / Purple (3)	White (1)
Leaf: length of blade	Short (<30 cm) (3) / Medium (30–45 cm) (5) / Long (>45 cm) (7)	Medium (5)
Leaf: width of blade	Narrow (<1 cm) / Medium (1–2 cm) / Broad (>2 cm)	Medium
Culm: attitude	Erect (1) / Semi erect (3) / Open (5) / Spreading (7)	Erect (1)
Time of heading (50% of plants with panicles)	Very early (<71 days) (1) / Early (71–90 days) (3) / Medium (91–110 days) (5) / Late (111–130 days) (7) / Very late (>131 days) (9)	Early (3)
Flag leaf: attitude of blade (early observation)	Erect (1) / Semi erect (3) / Horizontal (5) / Drooping (7)	Erect (1)
Spikelet: density of pubescence of lemma	Absent (1) / Weak (3) / Medium (5) / Strong (7) / Very strong (9)	Weak (3)
Male sterility	Absent (1) / Present (9)	Absent (1)
Lemma: anthocyanin coloration of the keel	Absent or very weak (1) / Weak (3) / Medium (5) / Strong (7) / Very strong (9)	Absent (1)

Table 4. *Cont*.

Characters	States	Hardinath Hybrid-1
Lemma: anthocyanin coloration of the area below the apex	Absent (1) / Weak (3) / Medium (5) / Strong (7) / Very strong (9)	Absent (1)
Lemma: anthocyanin coloration of apex	Absent (1) / Weak (3) / Medium (5) / Strong (7) / Very strong (9)	Absent (1)
Spikelet: colour of stigma	White (1) / Light green (2) / Yellow (3) / Light Purple (4) / Purple (5)	White (1)
Stem: thickness	Thin (<0.40 cm) (3) / Medium (0.40–0.55 cm) (5) / Thick (>0.55 cm) (7)	Medium (5)
Stem: length (including panicle; excluding floating rice)	Very short (<91 cm) (1) / Short (91–110 cm) (3) / Medium (111–130 cm) (5) / Long (131–150 cm) / (7): Very long (>150 cm) (9)	Medium (5)
Stem: anthocyanin coloration of nodes	Absent (1) / Present (9)	Absent (1)
Stem: intensity of anthocyanin coloration of nodes	Weak (3) / Medium (5) / Strong (7)	Weak (3)
Stem: intensity of anthocyanin coloration of internodes	Absent (1) / Present (9)	Absent (1)
Panicle: length of main axis	Very short (<16 cm) (1) / Short (16–20 cm) (3) / Medium (21–25 cm) (5) / Long (26–30 cm) (7) / Very long (>30 cm) (9)	Very long (9)
Flag leaf: attitude of blade (late observation)	Erect (1)/ Semi erect (3) / Horizontal (5) / Deflexed (7)	Erect (1)
Panicle: curvature of the main axis	Straight (1) / Semi straight (3) / Deflexed (5) / Drooping (7)	Deflexed (5)
Panicle: number per plant	Few (<11) / Medium (11–20) / Many (>20)	Medium
Spikelet: colour of tip of lemma	White (1) / Yellow (2) / Brown (3) / Red (4) / Purple (5) / Black (6)	Brown (3)
Lemma and palea color	Straw (1) / Gold and gold furrow on the straw background (2) / Brown spots on straw (3) / Brown furrow on straw (4) / Brown (5)/ Reddish to light purple (7) / Purple spots or furrow on straw purple (8) / Black (9)	Brown spots on straw (3)
Panicles: awn	Absent (1) / Present (9)	Present (9)
Panicle: colour of awns (late observation)	Yellowish white (1) / Yellowish brown (2) / Brown (3) / Reddish brown (4) / Light red (5) / Red (6) / Light purple (7) /Purple (8) / Black (9)	Yellowish white (1)
Panicle: length of longest awn	Very short (1)/ Short (3) / Medium (5) / Long (7) / Very long (9)	Very short (1)
Panicle: distribution of awn	Tip only (1) / Upper half only (3) / Whole length (5)	Tip Only (1)
Panicle: the presence of secondary branching	Absent (1) / Present (9)	Present (9)

Table 4. *Cont*.

Characters	States	Hardinath Hybrid-1
Panicle: secondary branching	Weak (1) / Strong (2) / Clustered (3)	Weak (1)
Panicle: attitude of branches	Erect (1) / Erect to semi-erect (3) / Semi erect (5) / Semi erect to spreading (7) / Spreading (9)	Semi erect (5)
Panicle: exertion	Partly exerted (3) / Mostly exerted (5) / Well exerted (7)	Well exerted (7)
Time of maturity	Very early (<100 days) (1) / Early (101–120 days) (3) / Medium (121–140 days) (5) / Late (141–160 days) (7) / Very late (>160 days) (9)	Medium (5)
Leaf senescence	Early (3) /Medium (5) / Late (7)	Medium (5)
Sterile lemma: color	Straw (1) / Gold (2) / Red (3) / Purple (4)	Straw (1)
Grain: weight of 1000 fully developed grains	Very low (<15 g) (1) / Low (15–20 g) (3) / Medium (21–25 g) (5) / High (26–30 g) (7) / Very high (>30 g) (9)	Medium (5)
Grain: length	Very short (<6 mm) (1) / Short (6.1–8.5 mm) (3) / Medium (8.6–10.5 mm) (5) / Long (10.6–12.5 mm) (7) / Very long (>12.5 mm) (9)	Long
Grain: width	Very narrow (<2 mm) (1) / Narrow (2.1–2.5 mm) (3) / Medium (2.6–3.0 mm) (5) / Broad (3.1–3.5 mm) (7) / Very broad (>3.5 mm) (9)	Very narrow
Grain: phenol reaction of lemma	Absent (1) / Present (9)	-
Decorticated grain: length	Short (1) / Medium (3) / Long (5)/ Long for basmati type (7) / Extra-long (9)	Extra long
Decorticated grain: width	Narrow (<2 mm) / Medium (2–2.5 mm) / Broad (>2.5 mm)	Narrow
Decorticated grain: shape (in lateral view)	Short slender (1) / Short bold (2) / Medium slender (3) / Long bold (4) / Long slender or long slender for basmati type (5) / Extra-long slender (6)	Extra-long slender
Decorticated grain: color	White (1) / Light brown (2) / Variegated brown (3) / Dark brown (4) / Light red (5) / Red (6) / Variegated purple (7) /Purple (8) /Dark purple (9)	White
Grain type	-	Long slender
Yield potential (t h^{-1})	-	6.5–8.2

Stability Analysis of Hardinath Hybrid-1

For sustainable production across diverse environments, it is important to have stable genotypes. The stable genotypes should lie close eigen line along with high yield potential. The Eigen line in a GGE biplot represents the principal component (PC1) axis, which explains the highest variance in the dataset. The eigenline (PC1) axis is crucial for identifying which genotypes perform consistently well. Understanding the Eigen line

helps in selecting genotypes with high and stable yields. Hardinath Hybrid-1 (HH-1) was evaluated in a multinational hybrid evaluation trial across four different agricultural stations over two representative years, 2017/18 and 2018/19. The inbred variety Chaite 5 and the hybrid variety Arize 6444 Gold were used as check varieties in both years. The GGE biplot analysis indicated that Hardinath Hybrid-1 (HH-1) is positioned near the center of the biplot i.e., near the eigenline, suggesting that it is highly stable and possesses broader adaptability, making it a variety suitable for wider growing conditions (Figure 1).

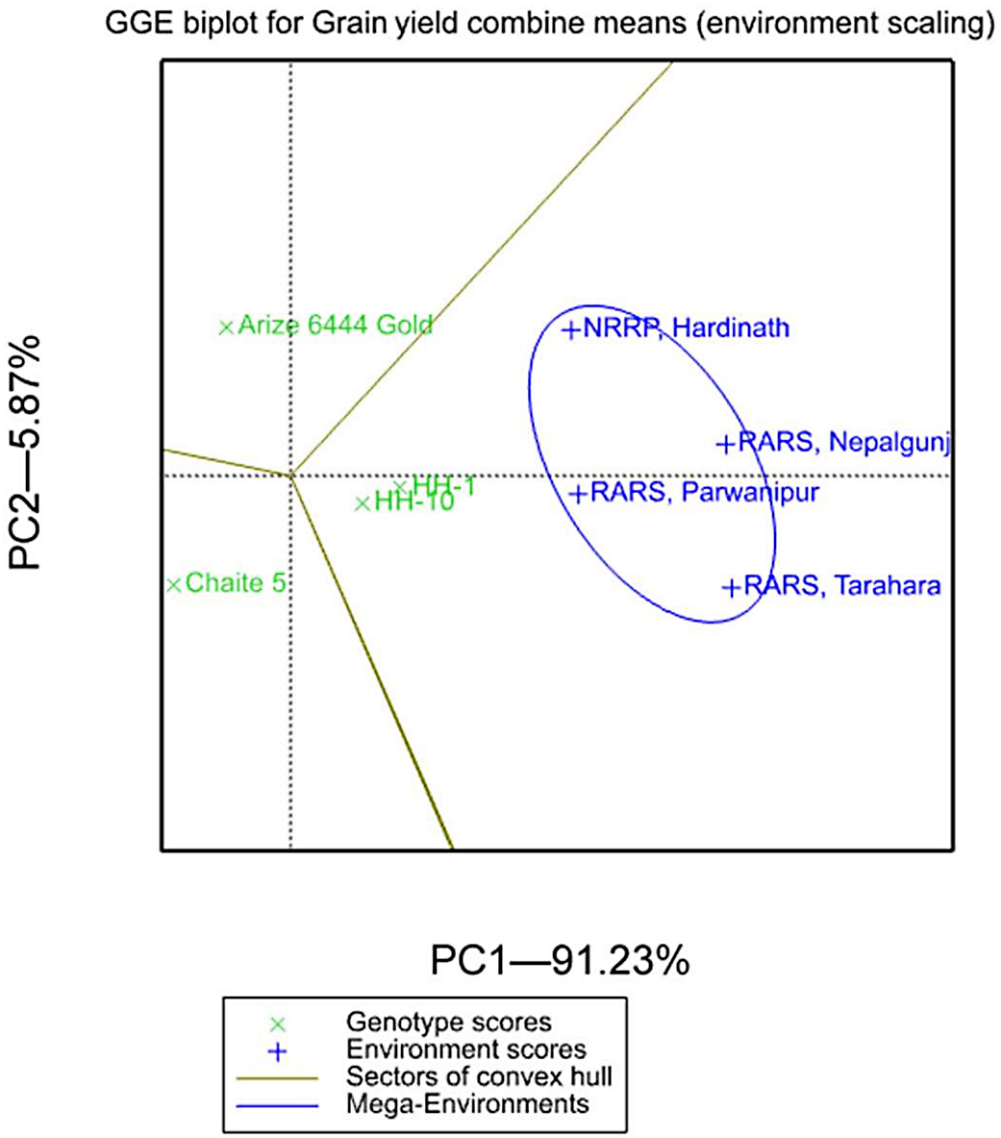

Figure 1. GGE Biplot of grain yield performance of Hardinath Hybrid 1. Note: NRRP, Hardinath—National Rice Research Program, Hardinath; RARS, Parwanipur—Regional Agriculture Research Station, Parwanipur; RARS, Nepalgunj—Regional Agriculture Research Station, Nepalgunj; RARS, Tarahara—Regional Agriculture Research Station, Tarahara.

CONCLUSION

Hardinath Hybrid-1 (HH-1) marks a significant achievement as the first hybrid rice variety developed and released for general cultivation by the National Rice Research Program, Hardinath. With a growing demand for hybrid seeds in Nepal, ranging from 2000–2200 tons, Hardinath Hybrid-1 meets the needs of high-input farmers seeking more productive options. The variety can yield up to 10 t ha^{-1} in the spring season [8]. In 2018/19, it consistently produced over 7 t ha^{-1} in areas like Hardinath and Nepalgunj. In all evaluations, it maintained yields above 6 t ha^{-1}. Even in farmers' fields, it has proven to be a reliable, high-yielding variety. This hybrid is adaptable to different environments and has shown strong performance in regions such as Kathmandu, Bhaktapur, Lalitpur, Kavrepalanchowk, Tanahu, Rupandehi, and Rauthahat.

DATA AVAILABILITY

The dataset of the study is available from the authors upon reasonable request.

AUTHOR CONTRIBUTIONS

Conceptualization, SRS and RBY; Methodology, SRS; Validation, DT, AP, RD, RR and PS; Formal Analysis, SRS; Investigation, RBY, SNS and BC; Data Curation, SRS and RR and PS; Writing—Original Draft Preparation, SRS; Writing-Review & Editing, RBY and RR; Supervision, RBY, SNS and BC; Project Administration, SRS.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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