PEARL MILLET: A NEW GREEN FODDER CROP IN KOREA

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ABSTRACT
Pearl millet (*Pennisetum americanum* (L.) Leeke) has been recognized in Korea since 1985, as an important new forage crop of high quality and yield. Suwon 1, pearl millet hybrid, was the best of 20 hybrids examined in Suwon, giving 150t/ha (three cuttings) of green fodder. The pearl millet hybrid was higher in green fodder yield than corn and sorghum/sudan grass hybrids. Leaf area index was 28.8 for three cuttings of pearl millet, with 5.8 for one cutting of maize, and 19.5 for three cuttings of sorghum/sudan grass. Crude protein content was 16.3% for pearl millet, 6 and 5% higher than corn and sorghum/sudan grass respectively. The digestibility of the whole plant was 57.6 to 63.4% for pearl millet, 46.3% for corn, and 47.3 to 57.6% for sorghum/sudan grass. Heavier nitrogen fertilizer applications increased green fodder yields, protein content and digestibility, but reduced the fat and ash content of pearl millet. The fodder yields and quality were dependent upon clipping time, interval and frequency.

KEYWORDS
Pear millet, green fodder crop, high yield in Korea.

INTRODUCTION
Pearl millet is a C_4 plant and summer crop originated from west Africa. It is the sixth most important cereal in the world and the most widely cultivated millet in the semi-arid tropics. It is grown on an estimated 25 million hectares. Pearl millet is a hardy cereal suited to dry regions with sandy infertile soils where rainfall is low and erratic, and can be successfully cultivated in areas too dry for sorghum. The grain is used to make unleavened bread (chapatis) in South Asia and prepared as gruel, dumplings, couscous and beer in Africa. It is also used as animal feed and forage in both temperate and tropical regions because it has a capability to grow well not only in the fertile soil, but also in the poor and dry soil. Pearl millet has been detected as a promising new forage crop of excellent quality and productivity in Korea since 1985. Its hybrids outyield cultivars under favorable conditions and show even greater superiority when grown under the abiotic and biotic stresses to which pearl millet is exposed. Many dairy farmers consider it superior to other pastures for milk production, and farmers producing beef and swine are using it to good advantage because the mean hydrocyanic acid potential (HCN-P) values for the crop are very low as compared with sorghum and sorghum/sudan grass hybrids. Superior hybrids and cultural techniques were developed for growing pearl millet of higher quality and green fodder yield. Thus, the objective of the paper was to introduce research highlights of pearl millet conducted and obtained from 1985 up to date at Crop Experiment Station, Rural Development Administration, Suwon, Korea.

MATERIALS AND METHODS
For the first time in 1985 and 1986, 656 pearl millet germplasms introduced from Australia, the United States of America and ICRISAT in India were planted at Crop Experiment Station, Suwon, Korea to determine the biological yield and quality as a forage crop and also for grain crop in Korea. Twenty hybrids were developed using superior male sterile lines and pollen parental lines well-adapted to Korean environmental conditions. The hybrids for forage were cut three or four times per year from July, August and through October from the green plants sown from late April through June. Cultivation trials using superior hybrid Chungaecho (Suwon 1) were carried out to investigate optimum planting time, depth, density and fertilizer application level, and to select preemergence herbicide for weed control just after planting. Optimum clipping time, interval and height of the hybrids were determined to increase forage yield and quality. Analysis of nutritional values for green fodder were obtained from the laboratory of the Livestock Experiment Station, Rural Development Administration in Suwon, Korea. Furthermore, the efficient hybrid seed production techniques for higher seed yield per unit area of the newly developed hybrids were determined using male sterile and fertile parental lines.

RESULTS AND DISCUSSION
Productivity of pearl millet introduced from ICRISAT. The pearl millet yielded from 64 to 154t/ha as fresh fodder, an average tested in Suwon, 1985, which were cut once in early September (Table 1). A hybrid, Suwon 1, was the best of the 20 tested throughout the country yielding 98t/ha on the average. It is possible to cut this hybrid three times a year. Plant height was three to four meters at maturity. The hybrid was taller, leafier, more tolerant to disease, with better quality and higher in fresh fodder yield than corn and sorghum/sudan grass hybrids. In Suwon, the Suwon 1 hybrid produced 147t/ha when cut three times, in early July, early August and mid-October, from plants sown in late April, 1986. In 1987, also, Suwon 1 hybrid was the best of the 10 hybrids giving 110t/ha on average, at 10 experimental sites around the county. Second was Suwon 6, which averaged 107t/ha and was more resistant to black streaked dwarf virus than Suwon 1. Fresh fodder yields of Suwon 6 were higher than Suwon 1 at Daegu and Junju where the disease occurs severely every year. In 1986, grain yields of ICMH 82205 and MBH 146 were the highest of the 13 hybrids evaluated at the six experimental sites, averaging 3.3 and 4.0t/ha. The highest grain yields of the two hybrids were 5.3t/ha at Muan and 5.8t at Jinju. In 1987, grain yield of ICMH 85049 was 4.1t/ha, the highest of the 22 hybrids tested. Second was ICMH 82205, which gave 3.7t/ha at Suwon.

A new pearl millet hybrid "Chungaecho" of high quality and high forage yield. Chungaecho is a single cross hybrid crossed between cytoplasmic male sterile line T23DA and fertile inbred line T186. The hybrid was renamed from Suwon 1 and evaluated over the country by Crop Experiment Station from 1986 to 1989. Chungaecho was 430cm in plant height with many tillers and ratooned well after cutting. The clipping height 20cm above the ground surface was the best resulting in producing 150 tons per hectare of green chop in two-year average of 1986 to 1987, and 192 tons per hectare when planted early in spring and mulched with polyethylene film in Suwon in 1987. Thus, the pearl millet hybrid was higher in green fodder yield than corn and sorghum/sudan grass hybrids. Leaf area index was 28.8 for the three times cut pearl millet, while 5.8 for the one time cut corn, and 19.5 for the three times cut sorghum/sudan grass. Crude protein content was 16.3 percent for pearl millet grain being six to five percent higher than corn and sorghum/sudan grass, 11.8 percent for the one time cut at maturity and 16.1 percent for four times cut being higher than corn and sorghum/sudan grass. The digestibility of whole plant was 57.6 to 63.4 percent for pearl millet, 46.3 percent for corn, and 47.3 to 57.6 percent for sorghum/sudan grass. Chungaecho produced 111t/ha in four-year average from 1986 to 1989 from the 10 experimental sites over the country. Dairy farmer's demonstration farm yield was 116t/ha in average of 10 places being higher than 79t/ha of sorghum/sudan grass in 1987. In the dairy farmer's actual proof trials of 1988 to 1989, Chungaecho produced 141 tons per hectare of green chop in average of eight places of Kyeongki province. Milk cows preferred pearl millet more than sorghum/sudan grass, and produced milk more. Thus, Chungaecho is a widely adaptable and high-yielding hybrid of excellent quality being recommended to livestock farmers in Korea.

Pre-sowing seed soaking and planting depth for dormancy breaking and seedling emergence of pearl millet. One of the most important cultural techniques of pearl millet is to encourage rapid and uniform emergence of seedlings to establish good stand and to let them grow well. The seeds with dormancy germinated 99 to 100 percent when soaked in the H_2O_2, 1% solution for 24 hours and rinsed with pure water, but germinated only 38% and 83% when soaked in pure water for 24 hours just after harvest and drying, and one month later from the harvest time, respectively. The seeds of Australia inbred line did not germinate at the constant 10°, but germinated at the constant 11° It also was possible to estimate the optimum planting season by applying minimum temperature 11° for germination. The minimum air temperature reached from late April in Suwon, Korea in regular years but fluctuated from late April to early May in 1986 and 1987. Thus, the safe planting season was mid-May for rapid and uniform germination of pearl millet seed. The optimum depth of planting was 2-4cm under the optimum soil moisture condition, and 4 to 6 cm under the drier soil moisture condition. Subcoleoptile internode (mesocotyle) length increased according to increased depth of planting. Seedling crown placement also became deeper due to deeper planting of the seeds. The subcoleoptile internode length and seedling crown depth were positively correlated with actual planting depth, indicating that deeper planting would be not good for appropriate adventitious root and tiller development.

Growing degree days and productivity by shifting planting dates in pearl millet. Days to emergence of Australia pearl millet inbred line were shortened from 12 days by delaying planting season from April 15 to July 15 in Suwon, 1986, but their growing degree days remained relatively constant 32.1° in average. Days to heading also were shortened from 96 days to 54 days shifting the planting season, but their growing degree days varied little being 697° in average. For grain crop, economic

planting season was from early May to late June, and their harvest index also did not vary much, but suddenly reduced in the July 15 planting plot. For forage crop, economic planting season was from mid-May to mid-June with optimum planting time of mid-May. Particularly, when planted in early July, 1987 and 1988, green fodder yields of Suwon 1 pearl millet hybrid were very low being 54 percent as compared with optimum planting season's yield 108t/ha. **Planting density and method for fodder yield of pearl millet.** Optimum planting density and method for fodder yield of pearl millet. Optimum planting density was 60°x15cm in dibbling, but in drilling 5kg of seed per hectare was good for higher fodder yield. **Fertilizer application levels for productivity and quality of pearl millet.** Plant height, green fodder yield, protein content and digestibility were increased by the increased fertilizer application level. However, the increased fertilizer application caused lodging, so that the plants grown above one meter in canopy height would be desirable to be clipped remaining 20cm above the ground surface before lodging, and fed to cattle. Mean green yields of the N 45-60kg/10a application were 12.7-13.4t/10a in the old upland soil. Increased phosphorus and potash fertilizer application also increased productivity, especially with potash fertilizer effect being higher than that of phosphorus fertilizer. In the newly reclaimed upland soil, improved and doubled fertilizer application plot of 60-60-40-4000kg/10a in N-P2O5-K2O-Compost was 38% higher being 12.6t/10a of green fodder yield as compared with standard fertilizer application plot. Pearl millet productivity and quality were higher than those of maize and sorghum/sudan grass hybrids, particularly in green fodder yield, protein content and digestibility. **Clipping method for forage yield and quality in pearl millet.** Clipping height 20 cm above the ground surface was the best resulting in producing 111 tons per hectare of green chop. However, clipping height 5 cm was not good for regrowth of the ratoon crop. Just after the first cutting when the plant height reached two meters around mid-July, four weeks cutting interval was the best for higher forage yield of 114 tons per hectare. Crude protein content of the clipping height 20 cm was the highest being 12.8 percent. Dry matter of the first cut contained 14 percent of crude protein being the highest, and with lower crude fiber content of 24 percent. And also four weeks cutting interval was the highest in crude protein content being 13.1 percent along with lower crude fiber content of 24.2 percent. Thus, the forage yield depended greatly on clipping height, but the quality was dependent upon clipping time, interval and frequency more than cutting height of the pearlmillet plant. It would be desirable for higher yield and quality of Suwon 1 pearl millet hybrid to cut three or four times during the growing season at 20 cm clipping height and at four weeks clipping interval from the first cut when the canopy height is above one meter under the Korean environmental conditions. Preemergence herbicide for controlling weeds in growing pearl millet. Propazine (Milogard 4L) was the best in controlling weeds without its phytotoxicity at the standard application rate, and with the highest survivalrate of seedlings of pearl millet hybrid. Alachlor killed pearl millet seedlings almost completely. Hybrid seed production techniques using male sterile and fertile inbred lines of perl millet. The highest seed production planting pattern was one row of pollen parent T186 to ten rows of seed parent T23DA for Suwon 1 hybrid, which was the same in hybrid seed yield as compared with two rows of pollen parent to twenty rows of seed parent, where the seed parent must be planted on May 15 being one month later than pollen parent's planting date for nicking their flowering and pollen shedding periods. The mean hybrid seed yields were 128kg/10a and 115kg/10a when planted on May 15 and May 25, 1989 respectively. When pollen parent T186 of Suwon 1, Suwon 6 and Suwon 18 hybridism was planted on May 5, 1989, its pollen began to shed from August 14 reaching 50% pollen shedding on August 17. When planted on May 10 to 15, its pollen shed on August 16 to 17 reaching 50% pollen shedding on August 20 to 21. When planted on May 25, its pollen shedding reached to 50% on August 28, 1989. Thus, the seed parent T23DA of Suwon 1 should be planted on May 23 to 25 for mating with pollen parent T186 planted on May 5 to 10, 1989. The seed parents ICM81A for Suwon 6and T85DA for Suwon 18 should be planted early June and on May 10 to 15 respectively for nicking their flowering and pollen shedding periods to produce the highest hybrid seed yields in Suwon.

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Table 1

Mean, maximum and minimum dates of heading, plant height and fresh fodder yield of 26 pearl millet varieties introduced from Australia and ICRISAT in India. Suwon (Korea), 1985.

Trait	Mean	Max.	Min.
Heading date	-	No heading	August 13
Plant height (cm)	213	266	100
Fresh fodder yield (t/ha)			
Harvested on September 3	107	154	64
Harvested on October 10	128	194	79

Table 2

Forage yield performance trial on pearl millet hybrid Chungaecho (Suwon: 1986-'87)

Crop (Hybrid)	Forage yield (t/10a)	Dry matter percentage (%)	Dry matter yield (t/10a)	Leaf area index	Highest forage yield ** (t/10a)
Pearl millet (Chungaecho)	15.0	17.7	2.8	28.8	19.2
Corn (Suwon 19) *	6.6	31.8	2.1	5.8	8.3
Sorghum/sudan grass (GW 9110)	11.1	28.2	2.7	19.5	14.3

* Corn harvested 40 days after silking (1986)

** '87 highest forage yield harvested from the early planted, heavy fertilized and polyethylene film mulched plot

Table 3

Effect of seed soaking on dormancy breaking and germination (Suwon, 1985) (Cultivar: Australia)

Chemicals	Seed soaking (hours)	Germination percentage (%) 1st	2nd	3rd	4th day
Expt. I (Oct.21, 25-30° C)					
H_2O_2 1%	24	0	93	96	99
H_2O_2 2%	24	0	85	95	96
Dce 1% + SH 0.5% [1]	1	0	7	18	69
H_2O_2 1% + DCE 1% + SH 0.5% [2]	1	0	85	98	98
H_2O	24	0	8	17	38
Expt. II (Nov.26, 15-25° C)					
H_2O_2 1%	24	0	85	91	100
H_2O	24	0	64	68	83

[1] DCE: Dichloroethanol, [2] : Sodium hypochlorite

Table 4

Effect of clipping time, interval and height on forage quality of pearl millet (Suwon, 1987)

(Unit: Percent)

Clipping method		Moisture	Crude Protein	Fat	Fiber	Ash	NFE *
Time	1st cut	10.3	14.0	2.6	24.0	14.9	34.2
	2nd cut	10.4	10.1	2.7	30.5	11.3	35.3
	3rd cut	10.5	11.7	2.7	24.1	12.9	38.1
	X	10.4	11.9	2.7	26.2	13.0	35.9
	S	0.1	2.0	0.1	3.7	1.8	2.0
	CV %	1.0	16.5	2.1	14.2	13.9	5.6
Interval	4 weeks	10.8	13.1	3.4	24.2	10.4	38.0
	6 weeks	10.9	12.2	2.6	25.9	9.4	38.7
	8 weeks	11.5	12.4	2.6	27.1	9.3	37.1
	X	11.1	12.6	2.9	25.7	9.7	37.9
	S	0.4	0.5	0.5	1.5	0.6	0.8
	CV %	3.4	3.8	15.9	5.7	6.3	2.1
Height	5cm	10.8	12.6	3.4	24.0	15.4	33.7
	20cm	10.0	12.8	3.0	25.1	12.9	36.3
	30cm	9.5	12.0	2.7	26.9	13.4	35.7
	40cm	11.6	11.5	2.0	26.5	12.6	35.7
	X	10.5	12.2	2.8	25.6	13.6	35.4
	S	0.9	0.6	0.6	1.3	1.3	1.1
	CV %	8.8	4.8	21.1	5.2	9.3	3.2

* NFE: Nitrogen free extract X : Mean value,
S: Standard deviation, CV: Coefficient of variation