

Review

Acorus calamus: An overview

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***Acorus calamus* (Sweet flag) is a wetland perennial monocot plant, in which the scented leaves and rhizomes have been traditionally used medicinally against different ailments like, fever, asthma, bronchitis, cough and mainly for digestive problems such as gas, bloating, colic, and poor digestive function. Number of active constituents and essential oil were identified and characterized from the leaves and rhizomes of sweet flag. An over view of the pharmacological activities and insecticidal activities are summarized here.**

Key words: *Acorus calamus*, *Acorus gramineus*, Acoraceae, active constituents, pharmacology.

INTRODUCTION

Mother earth has bestowed to the mankind and various plants with healing ability for curing the ailments of human being. This unique feature has been identified since pre historic times. The WHO has also estimated that 80% of the world population meets their primary health care needs through traditional medicine only. Medicinal plants are those plants possessing secondary metabolites and are potential sources of curative drugs with the very long list of chemicals and its curative nature. India is the eighth largest country having rich plant diversity with a total of around 47,000 species, of which more than 7500 species are being used as medicinal plants. Plant products are used as main source of medicine throughout the world for treating various human ailments. About 50% of the present day medicines in the United States of America are derived from natural sources especially from various plants (Copping, 1996). The use of traditional medicine in both developing and developed countries is significantly increasing in recent times.

There is a growing demand for medicines of Ayurveda, Siddha, Unani and Homeopathy for domestic consumption and export purposes. The world trade in plant based drugs and its products are many fold expanding continuously; because the general awareness of the wide spread toxicity and harmful after effects associated with the long-term use of synthetic drugs and antibiotics.

Estimate reveals that the world trade in medicinal plants and extracts industry was growing at a rate of 12 to 15% per annum. The export from India is to the tune of Rs 446 crores with the present growth rate of 7%. *Acorus calamus* is a tall perennial wetland monocot plant from the Acoraceae family. The scented leaves and rhizomes of sweet flag have been traditionally used as a medicine and the dried and powdered rhizome has a spicy flavour and is used as a substitute for ginger, cinnamon and nutmeg for its odor.

It is known by a variety of names, including cinnamon sedge, flag root, gladdon, myrtle flag, myrtle grass, myrtle sedge, sweet cane, sweet myrtle, sweet root, sweet rush and sweet sedge. *A. calamus* is probably indigenous to India and now found across Europe, Southern Russia, Northern Asia Minor, China, Japan, Burma, Sri Lanka, and Northern USA. *Calamus* was valued as a stimulant, bitter herb for the appetite and as an aid to the digestion. In North America, the decoction was used for fevers, stomach cramps and colic; the rhizome was chewed for toothache and powdered rhizome was inhaled for congestion. In Ayurvedic medicine *Calamus* is an important herb, and is valued as a "rejuvenator" for the brain and nervous system, and as a remedy for digestive disorders.

TAXONOMY

Kingdom: Plantae
Division: Magnoliophyta

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Class: Liliopsida
 Order: Acorales
 Family : Acoraceae
 Genus : *Acorus*
 Species: *calamus*/ *A. aromaticus* / *A. calamus* var. *americanus*
 Other species: *Acorus gramineus*

VERNACULAR NAMES

English- Sweet Flag
 Ayurvedic- Vacha
 Unani- Bacch
 Hindi- Bajai, Gora-bach, Vasa Bach
 Marathi- Vekhand
 Tamil- Vashambu
 Telugu- Vadaja, Vasa
 Kannada-Baje
 Malayalam-Vayambu
 Sanskrit- Bhutanashini, Jatila

BOTANY

A. calamus is a perennial plant with creeping and extensively branched, aromatic rhizome, cylindrical, up to 2.5 cm thick, purplish-brown to light brown externally and white internally. The leaves of *A. calamus* has a single prominent midvein and then on both sides slightly raised secondary veins and many, fine tertiary veins. This makes it clearly distinct from *Acorus americanus*. The leaves are between 0.7 and 1.7 cm wide, with average of 1 cm. The sympodial leaf of *A. calamus* is somewhat shorter than the vegetative leaves. The margin is curly-edged or undulate. Plants are very rarely flower or set fruit, but when they do, the flowers are 3 to 8 cm long, cylindrical in shape, greenish brown and covered in a multitude of rounded spikes. The spadix, at the time of expansion, can reach a length between 4.9 and 8.9 cm. The fruits are small and berry-like, containing few seeds. Flowers from early to late summer depending on the latitude, grows wild in marshy places up to 2000 m altitude in the Himalayas, Manipur, Naga Hills and in some parts of South India. There are only two species in the genus *Acorus*.

The other species in this genus is *Acorus gramineus* native to eastern Asia commonly called as Japanese sweet flag, Japanese rush, grassy-leaved sweet flag, dwarf sweet flag is an aquatic or wetland perennial with semi evergreen grass like foliage. It has narrow, 6 to 14 in (15 - 35.6 cm) glossy leaves and looks like thick, lush grass. The leaves are carried in two ranks, like opposing fans. They are flat, about a 0.5 in (1.3 cm) wide and tend to flop over. The insignificant flowers, shaped like little horns, are produced in midsummer on erect hollow stems. Usually, only plants grown in water produce flowers.

USES

Parts used

The parts used are leaves, root (rhizome) and stem. In Asia, Sweet flag has been used for at least the last 2000 years. The ancient peoples of China used it to lessen swelling and for constipation. In Ayurvedic medicinal practice India, the rhizomes have been used to cure several diseases like fever, asthma and bronchitis, and as a sedative. Native tribes used it to treat a cough, made a decoction as a carminative and as an infusion for cholera.

In Western herbal medicine the herb is chiefly employed for digestive problems such as gas, bloating, colic, and poor digestive function. Calamus helps distended and uncomfortable stomachs and headaches associated with weak digestion. Small amounts are thought to reduce stomach acidity, while larger doses increase deficient acid production, a good example of how different doses of the same herb can produce different results. It is a good sedative so that the extract is used for epilepsy, insanity and as a tranquillizer along with valeriana jatamansi and nardostacys grandiflora. It is an ingredient of any Ayurvedic preparation "Brahmi Bati" (Budhivardhar) which is indicated in epilepsy, coma, and hysteria and in cases of mental retardation; the same uses are prescribed for an *Acorus* containing Unani drug "Ma'jun Baladur".

CULTURAL ASPECTS

Soil and climate

It is a hardy plant found growing from tropical to sub-tropical climates. Plenty of sunshine should be available to the plant during its growth and after harvesting for drying the rhizomes. Temperature ranging from 10 to 38°C and annual rainfall between 70 and 250 cm are best suited. Cultivation should be avoided in places where there is no irrigation facility. This species comes up well in clayey loams, sandy loams and light alluvial soils of river banks.

LAND PREPARATION

The land should be ploughed twice or thrice prior to the onset of rains. The land should be prepared like paddy fields.

Propagation

Acorus is propagated through rhizomes. Rhizomes obtained from earlier planting are kept preserved in the soil and constantly kept moist. After emergence, the

rhizomes are cut into small pieces and planted. Sprouted rhizome pieces are planted at a spacing of 30 x 30 cm and depth of 4 cm in the month of July-August. The best time for planting is the second fortnight of June. Around 1, 11,000 plants can be planted per hectare. As the growth rate is very fast, sprouts are visible on the second day of planting.

Fertilizers

Compost/FYM @15 t per hectare along with nitrogen and phosphorus is applied. One third of N along with 50 kg of P and 25 kg of K is the basal requirement. The second dose of N should be given after one month of planting as broadcast and a third dose should be applied after two months of planting.

Irrigation

The river or canal banks where the land is saturated with water is very suitable for its growth. The initial level of water standing in the field should be 5 cm and later increased to 10 cm. Irrigation can be avoided in the rainy season, however, if there is prolonged dry spell it must be irrigated at an interval of 2 to 3 days.

Plant protection

Mealy bugs and caterpillar are the pests occurring on this crop. Spraying the shoots and drenching the roots of plants with 10 ml methyl parathion or 20 ml Quinolphos in 10 L of water can be effective in controlling the shoot and root mealy bugs. Major disease is leaf spot and a spray of Captan 10 g with Chloropyriphos 20 ml/10 L controls leaf spot as well as mealy bugs and caterpillar.

Harvesting and post harvest operations

After 6 to 8 months, in December, the lower leaves turn yellow and dry indicating their maturity. The field should be partially dried only leaving sufficient moisture for uprooting the plant. In case of large scale cultivation rhizomes may be removed by passing the plough. The uprooted rhizome is cleaned after washing with water and cut into size of 5 to 7.5 cm length and fibrous roots removed. The cut rhizomes are dried by spreading under the shade so that the amount of oil present in it is not harmed.

Yield

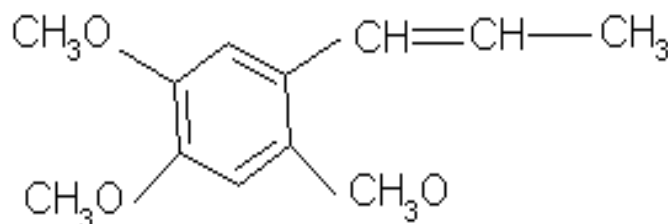
The yield is expected to be 4.22 t of dry rhizomes or 10 t fresh rhizomes per hectare.

Active constituents

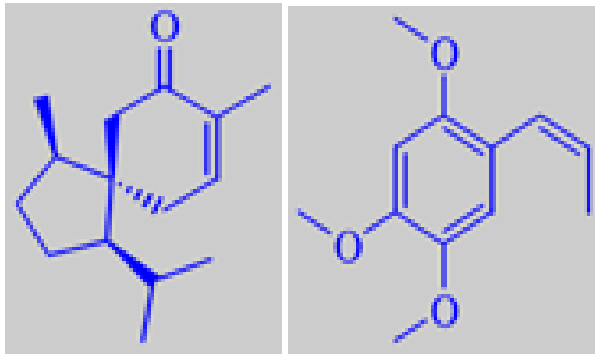
The rhizomes of *A. calamus* Linn. were examined by Asif et.al for the content and composition of fatty acids and sugars. Composition of the mixed fatty acids, as indicated by gas chromatography of the corresponding methyl esters, were myristic (1.3%), palmitic (18.2%), palmitoleic (16.4%), stearic (7.3%), oleic (29.1%), linoleic (24.5%) and arachidic (3.2%). The nature of the sugars was defined by paper chromatography and confirmed by direct comparison with authentic samples. Composition of the sugars, as indicated by densitometer, were maltose (0.2%), glucose (20.7%) and fructose (79.1%). The essential oil composition of Acorns *calamus* (sweet flag) leaves at different growing phases was examined by GC and GC/MS. The content of the oil in dried sweet flag rhizomes was 1.20+/-0.12% and in the leaves, depending on the vegetation phase, was from 0.56 to 1.01%. Beta-Asarone [(Z)-asarone] was the major constituent in the leaves (27.4 to 45.5%), whereas acorenone was dominant in the rhizomes (20.86%) followed by isocalamendiol (12.75%) (Venskutonsis et al., 2003). Besides Monoterpene hydrocarbons, sequestrine ketones, (trans- or Alpha) Asarone (2,4,5-trimethoxy-1-propenylbenzene), and Beta-asarone (cis- isomer) and eugenol were also identified (Kindscher and Kelly, 1992). The discovery of two plant lignans, epieudesmin and galgravin, in the leaves of the plant potentially explains several of the purported activities attributed to *Acorus calamus*. Some other compound identified in *A. calamus* are (-)-4-Terpineol, 2-Allyl-5-ethoxy-4-methoxyphenol, Epieudesmin, Lysidine, (-)-Spathulenol, Borneol, Furyl ethyl ketone, Nonanoic Acid, 2,2,5,5-Tetramethyl-3-hexanol, Bornyl acetate, Galgravin, Retusin, (9E,12E,15E)-9,12,15-Octadecatrien-1-ol, Butyl Butanoate, Geranylacetate, Sakuranin, Acetic Acid, Camphor, Isoelemicin, á-Ursolic acid, Acetophenone, Dehydroabiatic acid, Isoeugenol Methylene ether, Apigenin 4',7-dimethyl ether, Dehydrodiisoeugenol, Linalool, Elemicin, Linolenic acid (George et al., 1986).

Pharmacological activities

The rhizomes of *A. calamus* reportedly relieve stomach cramps, dysentery and asthma, and are used as:

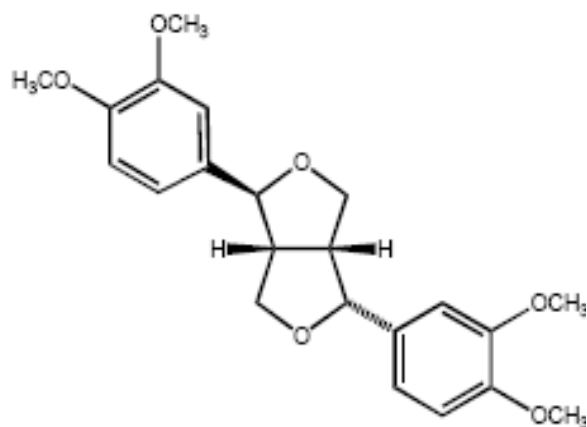


Asarone

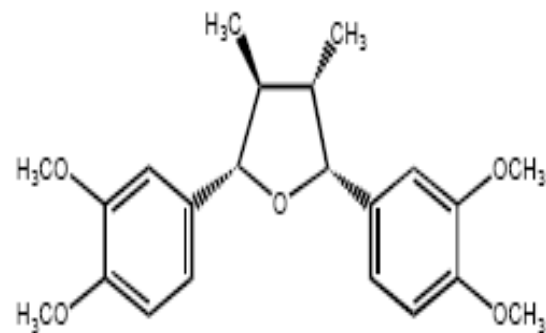


beta-Asarone

Acorenone



Epieudesmin



Galgravin

anthelmintics, insecticides, tonics and stimulants. Alcoholic rhizome extracts of *A. calamus* growing in KwaZulu-Natal, South Africa, were previously found to have anthelmintic and antibacterial activity. Using bioassay-guided fractionation, the phenylpropanoid β -asarone was isolated from the rhizome. This compound was shown to possess anthelmintic and antibacterial activity. It has previously been isolated from *A. calamus*, and a related species, *A. gramineus*. Different varieties of *A. calamus* exhibit different levels of β -asarone, with the diploid variety containing none of the compound. Mammalian toxicity and carcinogenicity of asarones has been demonstrated by other researchers, supporting the discouragement of the medicinal use of *A. calamus* by traditional healers (Van Staden, 2002).

Manikandan et al. (2005) reported that exposure to continuous loud noise is a serious health problem due to excess production of oxygen free radicals. In medical research, more attention is paid to the antioxidant properties of medicinal plants to minimize the harmful effects of radicals. The aim of this study was to evaluate the protective effect of both ethyl acetate and methanolic extract of *A. calamus* against noise stress (30 d, 100 dBA/4h/d) induced changes in the rat brain. They measured the activity of superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx) and the levels of reduced glutathione (GSH), vitamin C, vitamin E, protein thiols and lipid peroxidation (LPO) for the evaluation of oxidative stress status in discrete regions of the rat brain like cerebral cortex, cerebellum, ponsmedulla, midbrain, hippocampus and hypothalamus. The results indicated that during exposure of noisy environment ROS generation led to increase in corticosterone, LPO and SOD, but decrease in CAT, GPx, GSH, protein thiols, vitamins C and E levels. Both the ethyl acetate and methanolic extract of *A. calamus* protected most of the changes in the rat brain induced by noise-stress.

Antimicrobial activity

Experiment conducted by Phongpaichit et al. (2005) reported that a partially-purified fraction obtained from column chromatographic preparation of the crude methanol extract of *A. calamus* rhizomes were investigated for its antimicrobial activities on various microorganisms including bacteria, yeasts and filamentous fungi, exhibited high activity against filamentous fungi *Trichophyton rubrum*, *Microsporium gypseum*, and *Penicillium marneffeii* with IC₅₀ values of 0.2, 0.2 and 0.4 mg/ml, respectively. However, it showed moderate activity against yeasts: *Candida albicans*, *Cryptococcus neoformans* and *Saccharomyces cerevisiae* (MIC 0.1 to 1 mg/ml) and low activity against bacteria (MIC 5 - >10 mg/ml). Scanning electron microscopic observation revealed that hyphae and conidia treated with this fraction were shrunken and collapsed, which might be due to cell fluid leakage.

Antibacterial activity of *A. calamus* rhizomes is evaluated *in vitro*. Different concentrations of petroleum ether extract (50 to 2000 mg) are tested and the antimicrobial activity is observed from 500 mg and the zone of inhibition increases with concentration. The maximum activity is observed at 2000 mg and the highest concentration tested, beyond which the inhibition zone does not increase. Among the four types of bacteria tested, high inhibition zone is observed on *P. aeruginosa* (1.62 cm) followed by *S. aureus* (1.62 cm). *E. coli* and *B. subtilis* show smaller zone of inhibition (1.34 and 1.04 cm, respectively). MIC test shows that the minimum inhibition concentration is 0.25 mg/mL for *P. aeruginosa*,

S. aureus, *B. subtilis*, and 0.5 mg/mL for *E. coli* (Sabitha et al., 2003).

Dry and powdered rhizomes of *A. calamus* L. were extracted with ultrasonic bath using dichloromethane as solvent. Various concentrations (0.01 to 0.15%) of the extract were determined for antifungal activity on PDA agar against *Alternaria* spp. isolated from leaf spot and *Fusarium* spp. isolated from wilt diseases of cruciferous vegetable, as well as *Botrytis* spp. isolated from gray mold rot of roses and *Septoria* spp. isolated from leaf spot of chrysanthemum. The results indicated that all of the molds examined were sensitive to *A. calamus* extract. The growth of all tested fungi was completely inhibited at the concentration of 0.10% upward. Separation by preparative-TLC and guidance by TLC-bioassay using *Cladosporium cladosporioides* as a diagnostic fungus revealed an active compound that was identified as beta -asarone (cis-1,2,4-trimethoxy-5-(1-propenyl)-benzene) by GC-MS.

Modhumita (2006) fractionated *A. calamus* leaves by cation exchange chromatography and gel filtration and the fraction inhibiting the hyphal extension of phytopathogens was characterized purified protein was identified as a class III haem peroxidase with a molecular weight of approx. 32 kDa. The temperature stability of the enzyme was observed from 5 to 60°C with a temperature optimum of 36°C. Maximum enzyme activity was registered at pH 5.5. The pH and temperature optima were corroborated with the antifungal activity of the enzyme. The enzyme was localized in the leaf epidermal cells and lumen tissues of xylem, characteristic of class III peroxidases. The toxic nature of the enzyme which inhibited hyphal growth was demonstrated against phytopathogens, such as *Macrophomina phaseolina*, *Fusarium moniliforme* and *Trichosporium vesiculosum*. Microscopic observations revealed that distortion in the hyphal structure with stunted growth, increased volume and extensive hyphal branching.

Asha et al. (2009) evaluated Antimicrobial activity of *A. calamus* rhizome and leaf extracts obtained with different solvents viz., petroleum ether, chloroform, hexane and ethyl acetate against fungal pathogens and reported that Rhizomes and leaf ethyl acetate extracts exhibited pronounced antifungal activity with diameter zone of inhibition ranged from 20 to 28 and 18 to 25 mm as well as antiyeast activity with diameter zone of inhibition ranged from 22 to 25 and 20 to 23 mm, respectively. The minimum inhibitory concentration (MIC) of the rhizome and leaf extracts for antifungal activity measured was 2 to 4 mg/ml, except *Penicillium chrysogenum* whereas against yeasts was relatively higher, 4 to 5 and 6 to 8 mg/ml. MIC value for antibacterial activity was comparatively very high ~16 to 42 mg/ml. In addition, authentic α - and β -asarones were also tested for their antimicrobial potential. Both α - and β -asarones exhibited very strong antimicrobial activities against the fungi and yeasts than those of rhizome and leaf extracts. The study

clearly suggested that *A. calamus* rhizomes and leaves must possess active principle α - and β -asarones which is believed to be responsible for their antimicrobial activities

Antioxidant activity

Exposure of rats to acrylamide caused hind limb paralysis in 58% of the animals on day 10 and decreased behavioural parameters, namely distance travelled, ambulatory time, stereotypic time and basal stereotypic movements compared with the control group. These rats also had a decrease in the reduced glutathione (GSH) content and glutathione-S-transferase (GST) activity in the corpus striatum and an increase in striatal dopamine receptors, as evident by an increase in the binding of ^3H -spiperone to striatal membranes. Treatment with the ethanol: water (1:1) extract of the rhizomes of *A. calamus* increased the glutathione content and glutathione-S-transferase activity in the corpus striatum while insignificant changes were observed in other parameters. Rats treated with acrylamide and *A. calamus* extract in combination had a lower incidence of paralysis (18%) compared with those treated with ACR alone on day 10 of the experiment. The rats also showed a partial recovery in other behavioural parameters. The levels of GSH content and GST activity increased in the corpus striatum, while the dopamine receptors decreased compared with the ACR treated rats. The results suggest that the neurobehavioural changes produced by ACR may be prevented in the following treatment with *A. calamus* rhizomes (Pradeep et al., 2002).

Epieudesmin has been shown to have antineoplastic activity against the murine P388 lymphocytic leukemia cell line and several human cancer cell lines (BXPC-3, MCF-7, SF268, NCI-H460, KM20L2, and DU-145). (1) Galgravin has demonstrated activity in preventing neuronal death and stimulating neurite growth. Structurally, similar lignans have also shown neuroprotective activity in *in vitro* models for Alzheimer's and Parkinson's disease. (2) Both epieudesmin and galgravin were identified in the methanolic extracts of *A. calamus* leaves by liquid chromatography electron impact mass spectrometry (George et al., 2004).

The steam volatile fraction of the roots and rhizomes of *A. calamus* prolongs the sleeping time of mice when used with pentobarbital, hexobarbital and ethanol. It reduces body temperature of mice. The maximum reduction of body temperature and the potentiation of the hypnotic activity are observed 1 h after its administration. It exacerbates tonic seizures provoked by convulsive doses of Metrazol in rats and potentiates of the action of reserpine in reducing amphetamine toxicity in aggregated mice. The fall produced in the blood pressure of anesthetized rats is not prevented by vagal, adrenergic or ganglionic blockade and does not appear to be due to

any nervous mechanism. It causes dilatation of the blood vessels of the splanchnic area in cats and constricts the blood vessels of the frog's hind limbs. It prevents the action of acetylcholine, histamine and barium chloride on the isolated guinea pig's ileum.

Insecticidal activity

Asarones (2,4,5-trimethoxypropenyl-benzenes) isolated from the essential oil of *A. calamus* L. rhizomes, are potent growth inhibitors and anti-feedants to the variegated cutworm. *cis*-Asarone added to artificial diet significantly inhibited growth and feeding by first-, third-, and fourth-instar larvae, whereas the *trans* isomer produced an anti-feedant effect alone. Gross dietary utilization (efficiency of conversion of ingested food, ECI) was decreased when the diet was supplemented with *cis*-asarone or when this compound was topically applied to fourth-instar larvae. Inhibition of growth occurred even as a moderate topical dose (5 μ g/larva) primarily as a result of decreased efficiency of conversion of digested food (ECD), even though the approximate digestibility (AD) of the food was unchanged.

The insecticidal activities of compounds derived from the rhizomes of *A. gramineus* against four agricultural insect pests were examined using direct contact application method. The biologically active constituents of *A. gramineus* rhizomes were characterized as the phenylpropenes, *cis*- and *trans*-asarones by spectroscopic analyses. Potencies varied according to insect species, compound, and dose. In a test with female adults of *Nilaparvata lugens*, *cis*-asarone caused 100, 83 and 40% mortality at 1,000, 500 and 250 ppm, respectively, whereas 67% mortality was achieved at 1,000 ppm of *trans*-asarone. Against 3rd instar larvae of *Plutella xylostella*, *cis*-asarone gave 83 and 50% mortality at 1,000 and 500 ppm, respectively, whereas *trans*-asarone at 1,000 ppm showed 30% mortality. Against female adults of *Myzus persicae* and 3rd instar larvae of *Spodoptera litura*, *cis*- and *trans*-asarones both were almost ineffective at 2,000 ppm. The *A. gramineus* rhizome-derived materials merit further study as potential insect-control agents or as lead compounds against *N. lugens* and *P. xylostella*.

CONCLUSION

Even though, this studies supports the different pharmacological activities of Sweet flag lot of clinical

experiments will have to be conducted in future to exploit the full potential activities of this crop and this plant species has to properly identified and conserved to avoid the extinct condition.

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