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油菜素内酯对氯化钠胁迫下黄瓜幼苗的缓解效应*

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摘 要 研究了2,4-表油菜素内酯(EBR)对氯化钠胁迫下黄瓜幼苗叶片光合作用及抗氧化系统的影响. 结果表明: 与对照相比, 氯化钠胁迫导致黄瓜幼苗叶片超氧阴离子产生速率、过氧化氢和丙二醛含量、细胞膜透性显著升高, 净光合速率、气孔导度、蒸腾速率、胞间CO_2浓度显著下降, 幼苗生长显著受抑. EBR可提高黄瓜幼苗叶片超氧化物歧化酶、过氧化物酶、过氧化氢酶等抗氧化酶活性, 降低超氧阴离子产生速率、过氧化氢和丙二醛含量及细胞膜透性, 维持良好的光合性能, 从而促进幼苗生长, 有效缓解氯化钠胁迫造成的伤害.

关键词 黄瓜 氯化钠胁迫 油菜素内酯 光合 抗氧化系统
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Alleviation effects of brassinolide on cucumber seedlings under NaCl stress. LU Xiao-min[1], YANG Wei[2] ([1]*Anhui Science and Technology University*, *Fengyang* 233100, *Anhui*, *China*; [2]*Siping Station for Popularization of Agricultural Technique*, *Siping* 136000, *Jilin*, *China*). -*Chin. J. Appl. Ecol*., 2013, **24**(5): 1409-1414.

Abstract: This paper studied the effects of 2,4-epibrassinolide (EBR) on the photosynthesis and antioxidant system of cucumber seedling leaves under NaCl stress. As compared with the control, NaCl stress increased the leaf superoxide anion production rate, hydrogen peroxide content, malondialdehyde content, and cell membrane permeability while decreased the leaf net photosynthetic rate, stomatal conductance, transpiration rate, and intercellular CO_2 concentration significantly, and inhibited the seedlings growth significantly. Applying EBR could increase the activities of leaf superoxide dismutase, peroxidase, and catalase, decrease the leaf superoxide anion production rate, hydrogen peroxide content, malondialdehyde content, and cell membrane permeability, make the leaves keep a higher photosynthetic rate, and thus, promote the seedlings growth, being able to effectively alleviate the damage of NaCl stress.

Key words: cucumber; NaCl stress; brassinolide; photosynthesis; antioxidant system.

土壤盐渍化是农业生产及生态环境所面临的严峻问题[1]. 目前, 全球约有20%的耕地受到不同程度的盐害威胁[2], 而我国有10%的耕地属于盐渍化土壤[3], 另外, 随着设施栽培面积的迅速增加, 我国的土壤次生盐渍化问题日趋严重[4]. 研究表明, 盐可通过渗透和离子胁迫及营养失衡危害植物正常生长[5-6], 土壤盐分过高会引起植物体内抗氧化系统失衡、膜脂过氧化加剧、蛋白合成改变, 从而导致其光合性能下降、生长发育异常乃至死亡[7-10]. 因此, 如何有效缓解盐害胁迫一直是广大学者研究的热点领域.

油菜素内酯是20世纪末被发现的一种新型植物激素, 其作用不同于以往的五大类激素[[11]. 大量研究表明, 科学使用油菜素内酯能有效改善高温[12]、重金属[13]、干旱[14]、低氧[15]等不良环境下植物的抗氧化性能, 减少其膜脂过氧化程度, 从而促进植物的光合作用及干物质积累, 减轻逆境伤害[16-17]. 吴雪霞等[18]研究表明, 外源油菜素内酯能显著提高盐胁迫下茄子种子发芽势、发芽指数及抗氧化酶活性, 促进种子萌发和幼苗生长, 增强茄子的耐盐能力. 束红梅等[19]研究表明, 油菜素内酯可提高氯化钠胁迫下棉花叶片超氧化物歧化酶(SOD)、过氧化物酶(POD)、过氧化氢酶(CAT)等抗氧化酶活性, 减轻叶片膜脂过氧化程度, 缓解盐胁迫对棉花叶片的伤害. 宋士清等[20]研究表明, 油菜素内酯能显著降低氯化钠胁迫下黄瓜幼苗的盐害指数和死苗率, 提高其壮苗指数. 另外, 油菜素内酯还可通过改

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善植物的光合性能及硝酸还原酶活性来缓解盐对植物的危害[21-22]. 然而,有关油菜素内酯在提高植物抗盐性方面的研究报道仍较少. 为此,本文研究了2,4-表油菜素内酯(EBR)对氯化钠胁迫下黄瓜幼苗光合及抗氧化系统的影响,以明确油菜素内酯对氯化钠胁迫下黄瓜幼苗的保护机制,为利用油菜素内酯减轻作物盐害提供理论依据.

1 材料与方法

1.1 供试材料与试验设计

试验于2012年4—5月在安徽科技学院实习基地的温室内进行,以'津春2号'黄瓜品种为材料. 试验采用单因素随机区组设计,幼苗两叶一心时定植,5 d后进行各处理. 共设对照(CK)、氯化钠胁迫(N)、氯化钠胁迫+EBR(NB)3个处理. 用1/2 Hoagland营养液(pH 6.3±0.1)培养,其中,对照营养液不额外添加氯化钠,N和NB处理营养液添加70 mmol·L^{-1}氯化钠,同时NB处理叶面喷施0.01 mg·L^{-1}的EBR溶液. 幼苗培养、定植及处理后生长期间的温、湿度和光照管理按文献[23]进行. 每处理24株,设3次重复,处理后第8天测定株高、叶面积、鲜质量和干质量等营养指标,并选取第4片真叶进行相关生理指标的测定.

1.2 测定方法

营养指标按陆晓民等[23-24]的方法测定;CAT活性按照Dhindsa等[25]的方法测定;膜透性参照李合生[26]的方法测定;SOD和POD活性、丙二醛含量、超氧阴离子产生速率、过氧化氢含量参照陆晓民等[27]的方法测定;光合参数采用Li-6400光合仪,使用开放式气路,于9:00—11:00测定,设定叶室温度、光强、参比室CO_2浓度及相对湿度分别为(25±1)℃、1000 μmol·m^{-2}·s^{-1}、(380±10) μmol·L^{-1}、60%~70%,选择植株生长点下数第4片展开叶进行测定[23].

1.3 数据处理

用Excel 2003、DPS 7.05软件处理数据,采用Duncan法进行差异显著性检验(α=0.05).

2 结果与分析

2.1 油菜素内酯对氯化钠胁迫下黄瓜幼苗生长的影响

由表1可以看出,黄瓜幼苗在氯化钠胁迫下生长受抑,其株高、叶面积、植株鲜质量及总干质量等营养指标均较对照显著下降,仅分别为对照的73.8%、64.4%、67.5%和72.8%,而氯化钠胁迫下叶面喷施EBR后,黄瓜幼苗株高及地上部干质量均比单纯氯化钠胁迫有所增加,但差异均不显著,黄瓜幼苗叶面积、鲜质量、地下部干质量及总干质量却分别比单纯氯化钠胁迫处理显著提高了21.8%、24.0%、23.5%和17.2%. 可见,叶面喷施EBR有利于黄瓜幼苗生物量的积累,缓解了氯化钠对黄瓜幼苗生长的抑制程度.

2.2 油菜素内酯对氯化钠胁迫下黄瓜幼苗叶片抗氧化酶活性的影响

与对照相比,氯化钠胁迫处理的黄瓜幼苗叶片SOD和POD活性显著升高,分别增加了45.1%和68.4%,而施加EBR后黄瓜幼苗叶片SOD和POD活性较单纯氯化钠胁迫处理显著提高了22.5%和21.6%,而CAT活性也比对照和单纯氯化钠胁迫处理分别提高了34.4%和27.3%(图1). 可见,叶面喷施EBR可提高氯化钠胁迫下黄瓜幼苗叶片的抗氧化酶活性,从而增强植株对逆境的抗性,对植株起到有效的保护作用.

2.3 油菜素内酯对氯化钠胁迫下黄瓜幼苗叶片超氧阴离子产生速率和过氧化氢含量的影响

从图2可以看出,氯化钠胁迫下黄瓜幼苗叶片活性氧代谢失衡,其超氧阴离子产生速率加大,比对照提高了58.1%;同时其过氧化氢含量也比对照显著增加,增幅为56.4%. EBR处理的超氧阴离子产生速率、过氧化氢含量均比对照显著增加,但增幅比

表1 EBR对氯化钠胁迫下黄瓜幼苗生长的影响

Table 1 Effects of EBR on the growth of cucumber seedlings under NaCl stress (mean±SD)

处理 Treatment	株高 Plant hight (cm·plant^{-1})	鲜质量 Fresh mass (g·plant^{-1})	叶面积 Leaf area (cm^2·plant^{-1})	地上部干质量 Dry mass of shoot (g·plant^{-1})	地下部干质量 Dry mass of root (g·plant^{-1})	总干质量 Total dry mass (g·plant^{-1})
CK	22.5±1.2a	19.1±1.2a	306±22a	1.09±0.03a	0.27±0.02a	1.36±0.04a
N	16.6±1.0b	12.9±0.8c	197±13c	0.82±0.06b	0.17±0.08c	0.99±0.08c
NB	18.2±1.7b	16.0±0.6b	240±14b	0.95±0.05ab	0.21±0.02b	1.16±0.06b

CK:对照 CK; N:氯化钠胁迫 NaCl stress; NB:氯化钠胁迫+EBR NaCl stress+EBR. 同列不同小写字母表示处理间差异显著(P<0.05) Different small letters in the same column meant significant difference among treatments at 0.05 level.

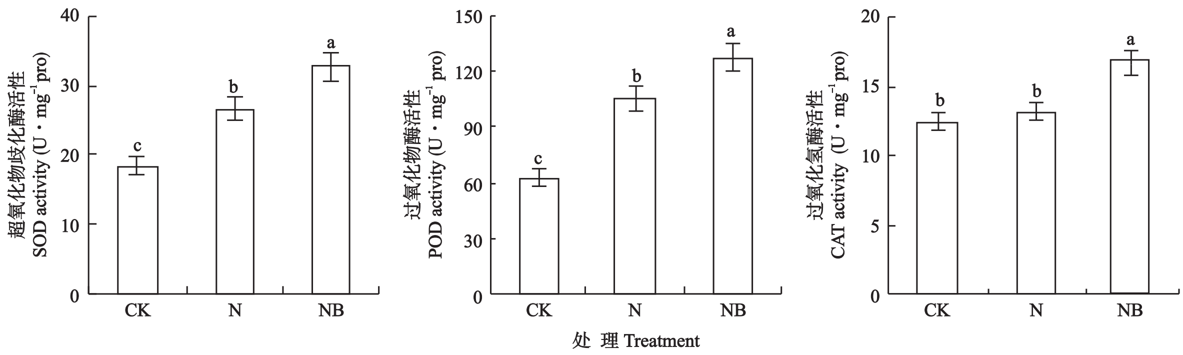

图 1　EBR 对氯化钠胁迫下黄瓜幼苗叶片 SOD、POD 和 CAT 活性的影响

Fig. 1　Effects of EBR on SOD, POD and CAT activities in leaves of cucumber seedlings under NaCl stress (mean±SD).

CK:对照 Control; N:氯化钠胁迫 NaCl stress; NB:氯化钠胁迫+EBR NaCl stress+EBR. 不同小写字母表示处理间差异显著(P<0.05) Different small letters meant significant difference among treatments at 0.05 level. 下同 The same below.

单纯氯化钠胁迫处理显著减少,其值仅为单纯氯化钠胁迫处理的 77.6% 和 83.6%,可见 EBR 能明显降低氯化钠胁迫下活性氧对黄瓜幼苗的伤害.

2.4　油菜素内酯对氯化钠胁迫下黄瓜幼苗叶片丙二醛含量和膜透性的影响

由图 3 可知,与对照相比,氯化钠胁迫下黄瓜幼苗叶片的丙二醛(MDA)含量和膜相对透性分别提高了 137.9% 和 152.1%,差异显著;而喷施 EBR 后,黄瓜幼苗叶片的丙二醛含量和膜相对透性比单纯氯化钠胁迫处理下降了 29.7% 和 19.6%. 说明 EBR 可减少氯化钠胁迫下黄瓜幼苗叶片膜脂过氧化程度,降低细胞膜透性,从而提高其对氯化钠胁迫的耐性.

2.5　油菜素内酯对氯化钠胁迫下黄瓜幼苗叶片光合作用的影响

由图 4 可知,与对照相比,氯化钠胁迫导致黄瓜幼苗叶片净光合速率(P_n)显著降低,降幅达 41.7%,其气孔导度(g_s)、蒸腾速率(T_r)和胞间 CO_2 浓度(C_i)也显著下降,降幅分别为 68.6%、56.4% 和 33.6%,而水分利用率(WUE)却显著提高了 78.8%. 叶面喷施 EBR 可缓解氯化钠胁迫下黄瓜幼苗 P_n、g_s 和 T_r 的下降幅度,其比单纯的氯化钠胁迫处理分别显著提高了 19.1%、31.5% 和 11.2%,但对 C_i 和 WUE 无显著影响.

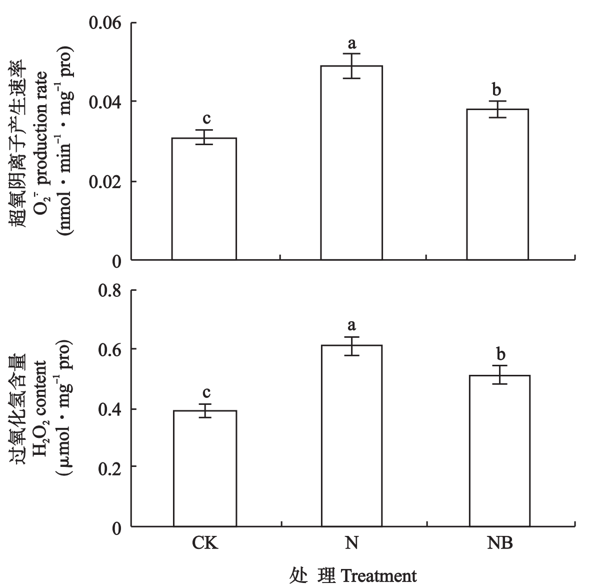

图 2　EBR 对氯化钠胁迫下黄瓜幼苗叶片超氧阴离子产生速率和过氧化氢含量的影响

Fig. 2　Effects of EBR on the superoxide anion production rate and hydrogen peroxide contents of cucumber seedling leaves under NaCl stress (mean±SD).

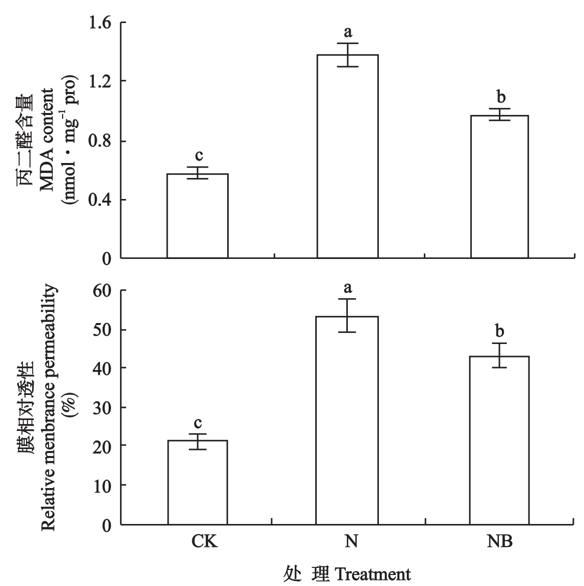

图 3　EBR 对氯化钠胁迫下黄瓜幼苗叶片丙二醛含量和细胞膜透性的影响

Fig. 3　Effects of EBR on MDA content and cell membrance permeability of cucumber seedling leaves under NaCl stress (mean±SD).

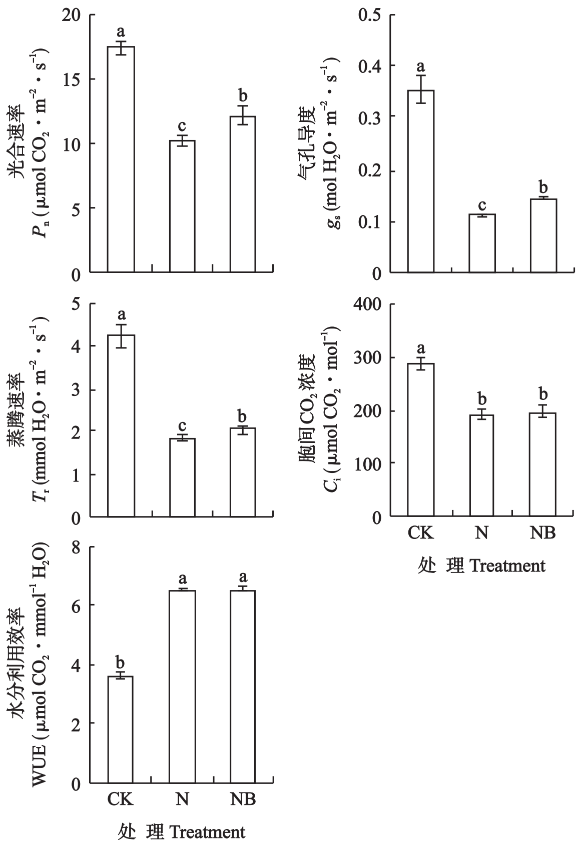

图4 EBR 对氯化钠胁迫下黄瓜幼苗叶片光合作用的影响
Fig. 4 Effects of EBR on photosynthesis of cucumber seedling leaves under NaCl stress (mean±SD).

3 讨 论

盐胁迫抑制植物生长的原因较复杂[28-30]. 刘国红等[31]研究发现,油菜植株在 200 mmol · L^{-1} NaCl 胁迫下处理至第 10 天,其光合速率下降 16%,幼苗干质量降低 56%,生长严重受抑. 光合速率的降低是导致盐胁迫下植物生长受抑的重要原因,维持盐胁迫下植物的光合性能已成为提高植物耐盐的重要途径[32-33]. 然而,诱导植物在盐胁迫下光合速率下降的因素很多,其气孔限制、活性氧水平和膜脂过氧化程度可直接影响植株光合性能[34].

盐胁迫下植物叶片细胞结构受损,光合性能下降[35]. 近年来,有关油菜素内酯的研究[36-37]表明,在逆境条件下油菜素内酯可通过有效调节植物的抗氧化性能,显著降低逆境对细胞亚结构的负作用,修复逆境对光合机构的伤害,提高其光合性能,从而缓解植物受害程度[38-40]. 从本试验结果来看,与对照相比,氯化钠胁迫下黄瓜幼苗叶片超氧阴离子产生速率、过氧化氢和丙二醛含量、细胞膜透性显著升高,气孔导度、蒸腾速率、胞间 CO_2浓度显著下降,导致净光合速率显著降低,幼苗的株高、叶面积、植株干鲜质量等营养指标均较对照显著减少,生长显著受抑. 盐胁迫下叶面喷施 EBR 能显著提高黄瓜幼苗叶片 SOD、POD、CAT 等抗氧化酶活性,降低其超氧阴离子产生速率、过氧化氢和丙二醛含量及细胞膜透性,有效缓解光合速率的下降,从而提高了氯化钠胁迫下黄瓜幼苗的叶面积、鲜质量及地下部干质量,增强了幼苗的抗盐性,促进了幼苗的生长. 另外,本试验还发现,盐胁迫下叶面喷施 EBR 能显著增加气孔导度,利于吸收更多的 CO_2,而胞间二氧化碳浓度变化不大,这可能是由于在盐胁迫下喷施 EBR 后,其光合速率显著增加,消耗了一定的二氧化碳,从而导致胞间二氧化碳浓度没有显著增加,说明 EBR 并非完全通过减少气孔限制来提高光合作用。

综上所述,氯化钠胁迫抑制黄瓜幼苗生长,叶面喷施 EBR 可显著提高氯化钠胁迫下黄瓜幼苗叶片的抗氧化酶活性,降低其活性氧含量及膜脂过氧化程度,维持了较高的光合性能,从而缓解了氯化钠胁迫对黄瓜幼苗的伤害.

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